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Indian Standard

TELECONTROL EQUIPMENT AND SYSTEMS

PART 5 TRANSMISSION PROTOCOLS

Section 2 Link Transmission Procedure

ICS 33.200

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

June 1998 **Price Group 14**

Power System Control and Associated Communications Sectional Committee, LTD 25

NATIONAL FOREWORD

This Indian Standard which is identical with IEC Pub 870-5-2 (1992 'Telecontrol equipment and systems — Part 5 : Transmission protocols, Section 2 : Link transmission procedures', issued by the International Electrotechnical Commission (IEC), was adopted by the Bureau of Indian Standards on the recommendation of Power System Control and Associated Communications Sectional Committee (LTD 25) and approval of the Electronics and Telecommunication Division Council.

The text of the IEC standard has been approved as suitable for publication as Indian Standard without deviations.

Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

CROSS REFERENCES

In this Indian Standard, the following International Standards are referred to. Read in their respective places the following:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 50 (371) : 1984 International Electrotechnical Vocabulary (IEV) — Chapter 371: Telecontrol	IS 1885 (Part 50) : 1985 Electrotechnical vocabulary: Part 50 Telecontrol (*first revision*)	Technically Equivalent
IEC 870-5-1 : 1990 Telecontrol equipment and systems — Part 5 : Transmission protocols — Section 1 : Transmission frame formats	IS 12746 (Part 5/Sec 1) : 1993 Telecontrol equipment and systems: Part 5 Transmission protocols, Section 1 Transmission frame formats	Identical

The concerned technical committee has reviewed the provisions of IEC 870-1-1 : 1988 'Telecontrol equipment and systems — Part 1: General considerations — Section 1: General principles', referred in this adopted standard and has decided that it is acceptable for use in conjunction with this standard.

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

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Indian Standard

TELECONTROL EQUIPMENT AND SYSTEMS

PART 5 TRANSMISSION PROTOCOLS

Section 2 Link Transmission Procedure

1 Scope and object

1.1 *Scope*

This section of IEC 870-5 applies to telecontrol equipment and systems with coded bit serial data transmission for monitoring and controlling geographically widespread processes.

The defined link procedures are restricted to message transmission sequences operating with size 1 windows. This means that the link layer of the primary station (station that initiates a message transfer) accepts a request for a new message transfer only when a previously accepted request for a message transfer is terminated either successfully or with an error indication. The procedures are applicable to balanced and unbalanced transmission in telecontrol systems using half duplex or duplex transmission channels.

1.2 *Object*

The standard transmission procedures defined by this section are applicable to point-to-point, multiple point-to-point, multipoint-star, multipoint-partyline and multipoint-ring configurations as described in 4.4 of IEC 870-1-1.

The data transmission functions in these systems are composed of three basic types of link transmission services, namely:

1. SEND/NO REPLY   2. SEND/CONFIRM   3. REQUEST/RESPOND

The two services SEND/CONFIRM and REQUEST/RESPOND consist of a sequence of non-separable dialogue elements between requesting stations and responding stations.

The protocol defined in this section accepts and processes only a single link transmission service at a time in each direction of a bidirectional communication system. Each transmission service is terminated either successfully or with error reports before the next transmission service begins. This means that the window size for successive packet transfers is 1 and the specified error recovery for the transmission services SEND/CONFIRM and REQUEST/RESPOND utilize the stop-and-wait method for automatic repeat requests (ARQ).

In point-to-point configurations equipped with duplex channel operation, the defined protocol supports balanced transmission procedures, that is simultaneous data transmission services in both directions of the communication link. This enables outstations to report spontaneous events to the control station as they occur, without having to be polled. This reduces reporting delays and leads to faster data acquisition. However, the use of an individual duplex communications channel to each outstation leads to increased equipment costs.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this section of IEC 870-5. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this section of IEC 870-5 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(371): 1984, *International Electrotechnical Vocabulary (IEV) – Chapter 371: Telecontrol.*

IEC 870-1-1: 1988, *Telecontrol equipment and systems – Part 1: General considerations – Section one: General principles.*

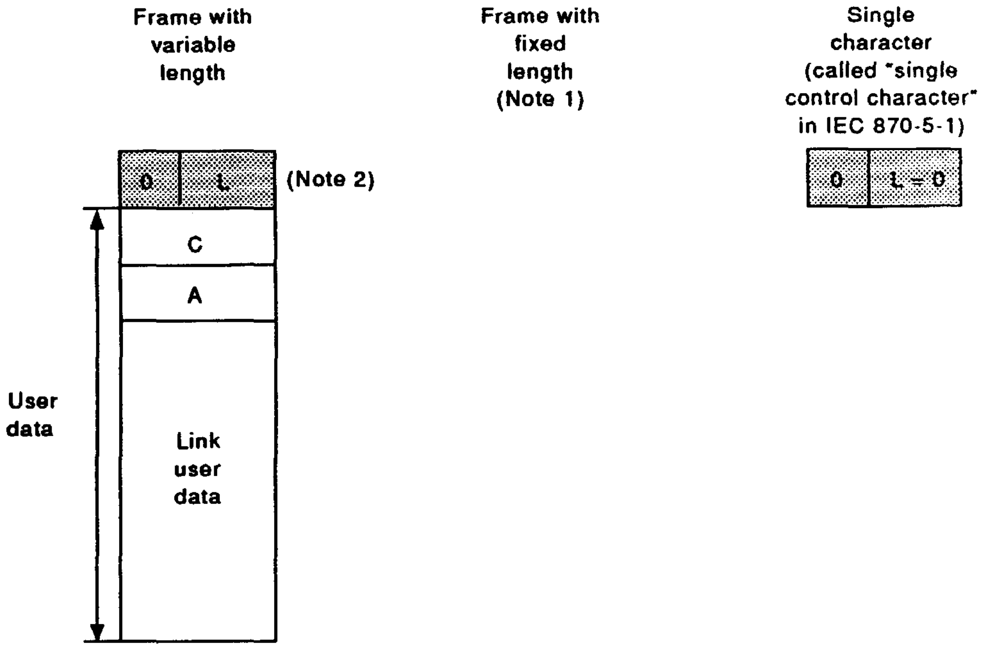
IEC 870-5-1: 1990, *Telecontrol equipment and systems – Part 5: Transmission protocols – Section One: Transmission frame formats.*

3 Formats and structures of standard transmission frames

The transmission procedures defined in this section provide protection against residual (i.e. undetected) transmission errors in the range of integrity class I1, specified in IEC 870-5-1, if the transmission frame format FT 1.1 is used and if the transmission rules specified by that section are observed. Residual transmission errors in the range of integrity class I2 are achieved if one of the transmission frame formats FT 1.2, FT 2 or FT 3, specified by that section, are utilized and if the corresponding transmission rules are observed. Only one chosen transmission frame format may be used on any given physical communications channel in a system. The order of fields in the frames is generally as follows:

Length (one octet)
Control (one octet)
Address (one or more octets, by agreement)
Link user data (n octets)

3.1 *Format FT 1.1*


Frame with variable length
Frame with fixed length (Note 1)
Single character (called "single control character" in IEC 870-5-1)
0
L
(Note 2)
C
A
User data
Link user data
0
L = 0

L: length field range: 0...127
L specifies the number of subsequent user data octets including the control and address fields

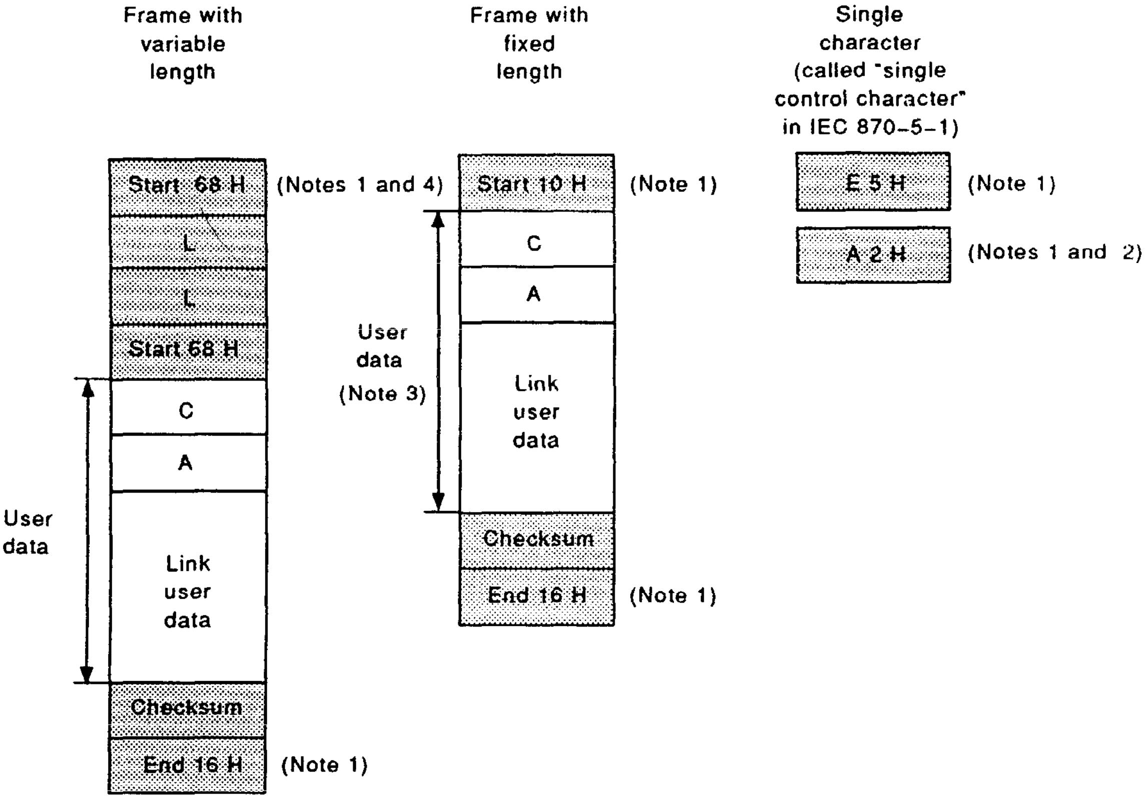
C: control field
A: address field, optional

NOTES

1 There is no special frame with a fixed length; the variable length frame is used in all cases.

2 The shaded fields have already been defined in IEC 870-5-1.
The unshaded fields are the "user data" of the frame as indicated in IEC 870-5-1.

3.2 *Format FT 1.2*



L: length field range: 0...255
L specifies the number of subsequent user data octets including the control and address fields

C: control field
A: address field, optional

NOTES

1 Specified data octets are represented in hexadecimal notation, in which
bits with weights 2^7 ... 2^4 denote the left hexadecimal character and
bits with weights 2^3 ... 2^0 denote the right hexadecimal character,

e.g.: $68\text{ H} = \underset{6}{\underline{0110}}\ \underset{8}{\underline{1000}}$

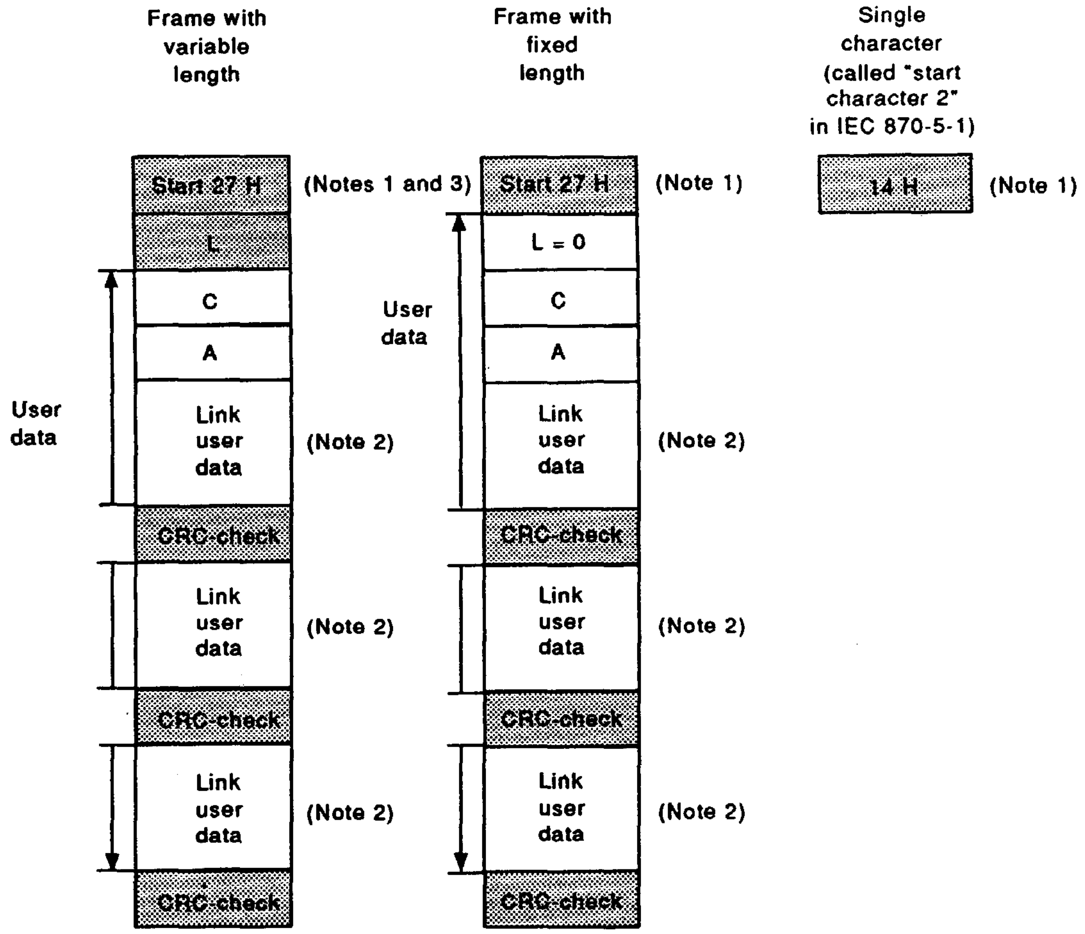
The sequence of bit transmission begins, as defined in IEC 870-5-1, with the least significant bit 2^0.

2 Reserved for special use by agreement.

3 A fixed number of user data octets is specified per system.

4 The shaded fields have already been defined in IEC 870-5-1.
The unshaded fields are the "user data" of the frame as indicated in IEC 870-5-1.

3.3 *Format FT 2*



L: length field range: 0...255
L specifies the number of subsequent user data octets including the control and address octets and excluding the CRC-check octets

L = 0 specifies a fixed frame length with at least 2 user data octets
L > 0 specifies a variable frame length with L user data octets

C: control field
A: address field, optional
CRC-check: Cyclic Redundancy Check

NOTES

1 Specified data octets are represented in hexadecimal notation,

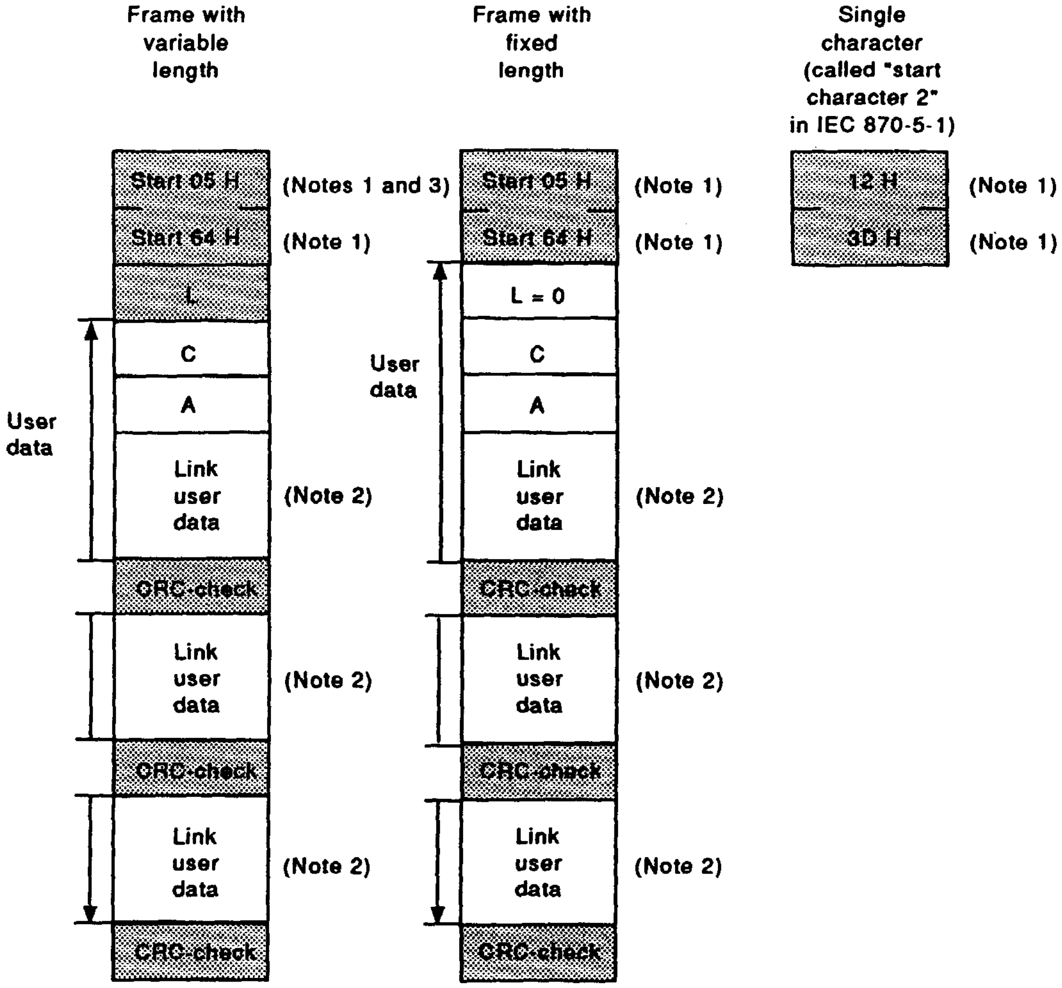
$$\text{e.g. } 27\,H = \frac{0010}{2}\ \frac{0111}{7}$$

The sequence of bit transmission begins, as defined in IEC 870-5-1, with the most significant bit.

2 Up to 15 user data octets are completed by a CRC-check octet (see IEC 870-5-1, subclause 6.2.4.3.1, R3).

3 The shaded fields have already been defined in IEC 870-5-1.
The unshaded fields are the "user data" of the frame as indicated in IEC 870-5-1.

3.4 *Format FT 3*



L: length field range: 0...255
L specifies the number of subsequent user data octets including the control and address octets and excluding the CRC-check octets

L = 0 specifies a fixed frame length with at least 2 user data octet
L > 0 specifies a variable frame length with L user data octets

C: control field
A: address field, optional
CRC-check: Cyclic Redundancy Check

NOTES

1 Specified data octets are represented in hexadecimal notation,

e.g. $05\,H = \underset{0}{\underline{0000}}\ \underset{5}{\underline{0101}}$ $\quad 64\,H = \underset{6}{\underline{0110}}\ \underset{4}{\underline{0100}}$

The sequence of bit transmission begins, as defined in IEC 870-5-1, with the most significant bit.

2 Up to 16 user data octets are completed by a CRC-check octet (see IEC 870-5-1, subclause 6.2.4.4.1, R3).

3 The shaded fields have already been defined in IEC 870-5-1.
The unshaded fields are the "user data" of the frame as indicated in IEC 870-5-1.

4 Service primitives and elements of transmission procedures

The data communication is described by

"service primitives"	crossing the interface between the service user and the link layer, and associated
"transmission procedures"	of the link between communicating stations.

The contents of the service primitives (parameters, conditions, etc.) are not standardized in this section.

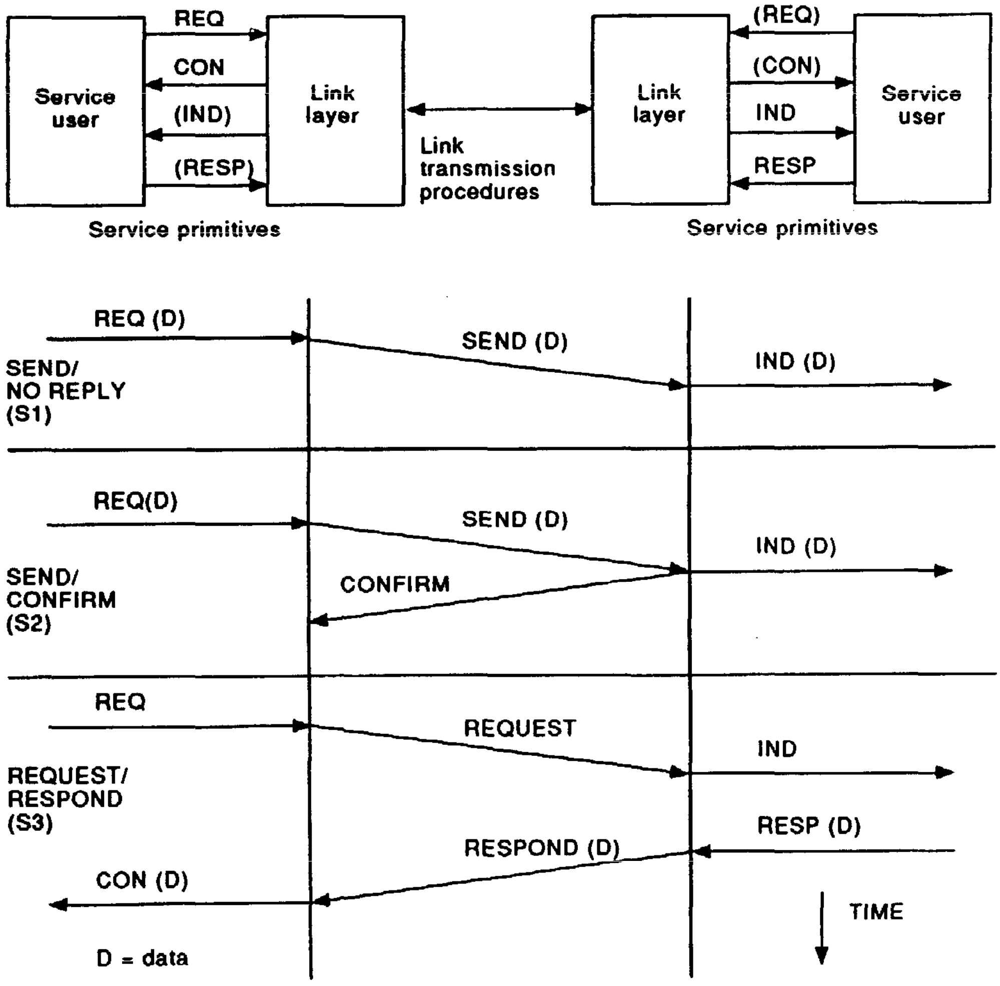


Figure 1 – Relationship between service primitives and transmission procedures for basic link services

Figure 1 shows error free transmission procedures of basic link services. Transmission errors are only detected by receiving stations. A secondary station receiving a disturbed SEND or REQUEST frame does not reply. This is detected by the primary station timing out, because the expected CONFIRM or RESPOND frame is not received. Also a primary station receiving a disturbed CONFIRM or RESPOND frame ignores it and consequently detects the error.

There are four types of primitives that may contain user data and sets of parameters and conditions, namely:

request primitive REQ:	a request issued by the service user to invoke some procedure in the link layer;
confirmation primitive CON:	a confirmation issued by the link layer to complete the procedure previously invoked by a request;
indication primitive IND:	a indication issued by the link layer to announce the wish to deliver data to the service user, or to invoke some service user procedure;
response primitive RESP:	a response issued by the service user to announce the completion of a procedure previously invoked by an indication.

NOTE - Confirmations or responses can be positive or negative, as appropriate to the circumstances.

Typical contents of the service primitives are parameters, conditions and user data as follows:

user data;

types of transmission service (function code, e.g. SEND/CONFIRM);

negative/positive confirmations or responses;

DFC (data flow control);

ACD (access demand);

number of repetitions (e.g. 3);

error status (e.g. after a repeated transmission error);

status of the layer (e.g. restart conditions).

4.1 *SEND/NO REPLY service*

4.1.1 *Service primitives*

– Primary station

The link layer accepts the request primitive REQ (SEND/NO REPLY) given by the link user when it is able to transmit the message. If the link layer is not able to transmit the message (disconnection from line or error state) a negative confirmation primitive CON (negative, SEND/NO REPLY, error status) is returned.

- Secondary station

An indication primitive IND (no response required) announces the reception of the message to the service user of the secondary station.

4.1.2 *Transmission procedure*

The specified SEND frame (see tables 1 and 3) is transmitted when the transmission procedure of a previous service is terminated

After the transmission of the frame a line idle interval is provided whose length is specified as an interval between frames upon detection of a transmission error (see IEC 870-5-1, subclause 6.2.4.1, transmission rule R4 for FT 1.1 frames, subclause 6.2.4.2.1, transmission rule R4 for FT 1.2 frames, subclause 6.2.4.3.1, transmission rule R5 for FT 2 frames and subclause 6.2.4.4.1, transmission rule R5 for FT 3 frames).

The line idle interval may be reduced below these figures by using the carrier off condition to represent idle line.

4.2 *SEND/CONFIRM service*

4.2.1 *Service primitives*

- Primary station

The link layer accepts the request primitive REQ (SEND/CONFIRM, number of repetitions) and invokes the SEND/CONFIRM procedure, unless it is unable to transmit the message, in which case it returns a negative confirmation primitive CON (negative SEND/CONFIRM, error status) to the service user.

If a negative acknowledgement is received from the secondary station, a negative confirmation primitive CON (negative SEND/CONFIRM, error status) is returned to the user. A negative confirmation primitive is also returned to the user if the maximum number of repeated message transmissions expires without success.

- Secondary (confirming) station

An indication primitive IND (no response required) announces the reception of the message to the user at the confirming station if a SEND frame which is not a repeat of the previously received frame is received in the designated destination.

4.2.2 *Transmission procedure*

The specified SEND frame (see tables 1 and 3) is transmitted when the transmission procedure of a previous service is terminated.

When it is received correctly by the secondary station a positive CONFIRM (ACK) is transmitted to the primary station.

If the confirming station is unable to accept the message, e.g. due to an overload situation (unavailable buffer memory), a negative CONFIRM frame (NACK, message not accepted) is transmitted.

4.2.2.1 *Protection against loss and against duplication of message transmission*

In the primary station the frame count bit (FCB, see 5.1.2) is alternated with each new SEND/CONFIRM service. The service is terminated when an error free CONFIRM frame is received.

If the CONFIRM frame is disturbed or timed out, then the SEND frame is repeated with unchanged FCB bit. The maximum number of repetitions is a specified parameter.

In the secondary station a copy of the confirm message returned to the primary station is stored. If the value of the FCB bit in the next SEND frame is alternated from the previous one (as expected), then the memorized confirm message is cleared and may be overwritten; otherwise, the received message is discarded and the memorized CONFIRM frame is transmitted again. On receiving a reset command, which has an FCB equal to zero (see tables 1 and 3), the secondary station will be set to expect the next frame primary to secondary with FCV = valid (FCV=1, see 5.1.2) to have the opposite setting of FCB, i.e. FCB equal to one.

4.3 *REQUEST/RESPOND service*

4.3.1 *Service primitives*

- Primary (requesting) station

The link layer accepts the request primitive REQ (REQUEST/ RESPOND, number of repetitions) and invokes the REQUEST/RESPOND procedure after a previous transmission procedure is terminated, unless it is not able to transmit the message, in which case it returns a negative confirmation primitive CON (negative REQUEST/RESPOND, error status) to the user.

If the procedure ends with the requested response from the secondary station, the link layer gives a confirmation primitive CON (response to request) to the user.

If a negative acknowledgement is received from the secondary station (data are not available), the link layer gives a negative confirmation primitive CON (negative response to request, error status) to the user.

A negative confirmation primitive CON (negative response to request, transmission error) is also returned to the user if the maximum number of repeated request transmissions expires without success.

- Secondary (responding) station

When a REQUEST frame is received the link layer issues an indication primitive IND to the user. If the requested data are available, the link user returns a response primitive RESP with the data to the link layer; otherwise, it returns the response primitive RESP (requested data not available).

4.3.2 *Transmission procedures*

The specified REQUEST frame (see table 1) is transmitted when the transmission procedure of a previous service is terminated.

On receiving a REQUEST frame the secondary station will send

a RESPOND frame (see table 2) with the requested data if available;

a RESPOND NACK frame "requested data not available" if the data are not available.

4.3.2.1 *Protection against loss and against duplication of message transmission*

In the primary station the frame count bit FCB is alternated with each new REQUEST/ RESPOND service. If an error-free RESPOND frame (RESPOND, NACK frame or NACK single character) is received, then the service is terminated by returning the received reply to the user.

If the RESPOND frame is disturbed or timed out, then the REQUEST frame is repeated with unchanged FCB bit. The maximum number of repetitions is a specified parameter.

In the secondary station the received frame count bit and the transmitted response are buffered locally. If a REQUEST frame is received with an alternated FCB bit, then the memorized response may be cleared. However, if a REQUEST frame with the same FCB bit is received, then the same response is repeated.

5 Unbalanced transmission

Unbalanced transmission procedures are used in supervisory control and data acquisition (SCADA) systems in which a master station controls the data traffic by polling outstations sequentially. In this case the master station is the primary station that initiates all message transfers while the outstations are secondary stations that may transmit only when they are polled.

The following transmission services, initiated by the primary station, are supported by the link:

SEND/NO REPLY	mainly used for global messages and for cyclic setpoints in control loops;
SEND/CONFIRM	mainly used for control commands and setpoint commands;
REQUEST/RESPOND	used for polling; sequences of this service may be used for cyclic updating functions.

5.1 *Specification of length, control and address fields*

5.1.1 *Length field*

The length field is as defined in 6.2.4 of IEC 870-5-1 and also in this section in 3.1 to 3.4.

5.1.2 *Control field*

The control field contains information that characterizes the direction of the message, the type of the service provided and supports control functions for suppressing losses or duplications of messages.

	MSB							LSB	
Control field	RES	1 PRM	FCB	FCV	2^3	2^2	2^1	2^0	Primary to secondary
		PRM 0	ACD	DFC	Function				Secondary to primary
Bit:	8	7	6	5	4	3	2	1	

RES: reserved

FCB: frame count bit: 0,1 = alternating bit for successive SEND/CONFIRM or REQUEST/RESPOND services per station.

The frame count bit is used to delete losses and duplications of information transfers. The primary station alternates the FCB bit for each new SEND/CONFIRM or REQUEST/RESPOND transmission service directed to the same secondary station. Thus the primary station keeps a copy of the frame count bit per secondary station. If an expected reply is timed out (missing) or garbled, then the same SEND/CONFIRM or REQUEST/RESPOND service is repeated with the same frame count bit.

In case of reset commands (see table 1) the FCB bit is always zero, and upon receipt of these commands the secondary station will always be set to expect the next frame primary to secondary with FCV = valid (FCV=1) to have the opposite setting of FCB, i.e. FCB equal to one.

FCV: frame count bit valid: 0 = alternating function of FCB bit is invalid;
1 = alternating function of FCB bit is valid.

SEND/NO REPLY services, broadcast messages and other transmission services that ignore the deletion of duplication or loss of information output do not alternate the FCB bit and indicate this by a cleared FCV bit.

DFC: data flow control: 0 = further messages are acceptable;
1 = further messages may cause data overflow.

Secondary (responding) stations indicate to the message initiating (primary) station that an immediate succession of a further message may cause a buffer overflow.

ACD: Access demand: There are two classes of message data provided, namely class 1 and 2;
0 = no access demand for class 1 data transmission;
1 = access demand for class 1 data transmission.

Secondary stations indicate to the primary station the wish for class 1 data transmission.

NOTE - Class 1 data transmission is typically used for events or for messages with high priority. Class 2 data transmission is typically used for cyclic transmission or for low priority messages.

PRM: primary message: 0 = message from secondary (responding) station;
1 = message from primary (initiating) station.

Table 1 – Unbalanced transmission, function codes of control field in messages sent from primary (PRM = 1)

Function code No.	Frame type	Service function	FCV
0	SEND/CONFIRM expected	Reset of remote link	0
1	SEND/CONFIRM expected	Reset of user process	0
2	SEND/CONFIRM expected	Reserved for balanced transmission procedure	–
3	SEND/CONFIRM expected	User data	1
4	SEND/NO REPLY expected	User data	0
5		Reserved	–
6 - 7		Reserved for special use by agreement	–
8	REQUEST for access demand	Expected response specifies access demand	0
9	REQUEST/RESPOND expected	Request status of link	0
10	REQUEST/RESPOND expected	Request user data class 1	1
11	REQUEST/RESPOND expected	Request user data class 2	1
12 - 13		Reserved	–
14 - 15		Reserved for special use by agreement	–

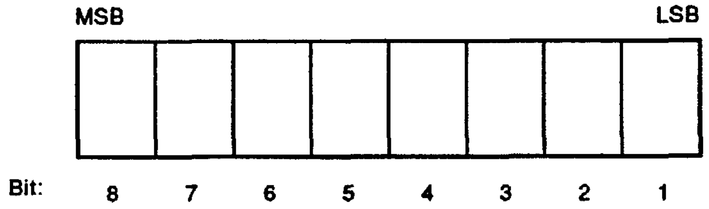
Table 2 – Unbalanced transmission, function codes of control field in *messages sent from secondary* (PRM = 0)

Function code No.	Frame type	Service function
0	CONFIRM	ACK: positive acknowledgement
1	CONFIRM	NACK: message not accepted, link busy
2 - 5		Reserved
6 - 7		Reserved for special use by agreement
8	RESPOND	User data
9	RESPOND	NACK: requested data not available
10		Reserved
11	RESPOND	Status of link or access demand
12		Reserved
13		Reserved for special use by agreement
14	–	Link service not functioning
15	–	Link service not implemented

5.1.3 *Address field*

The address field specifies the station address. It is transmitted in frames from stations that initiate a data transmission service ("primary stations") to receiving stations ("secondary stations") and specifies the destination address. The address field of frames transmitted by secondary stations specifies the source address.

Address field:



LSB: Least significant bit
MSB: Most significant bit

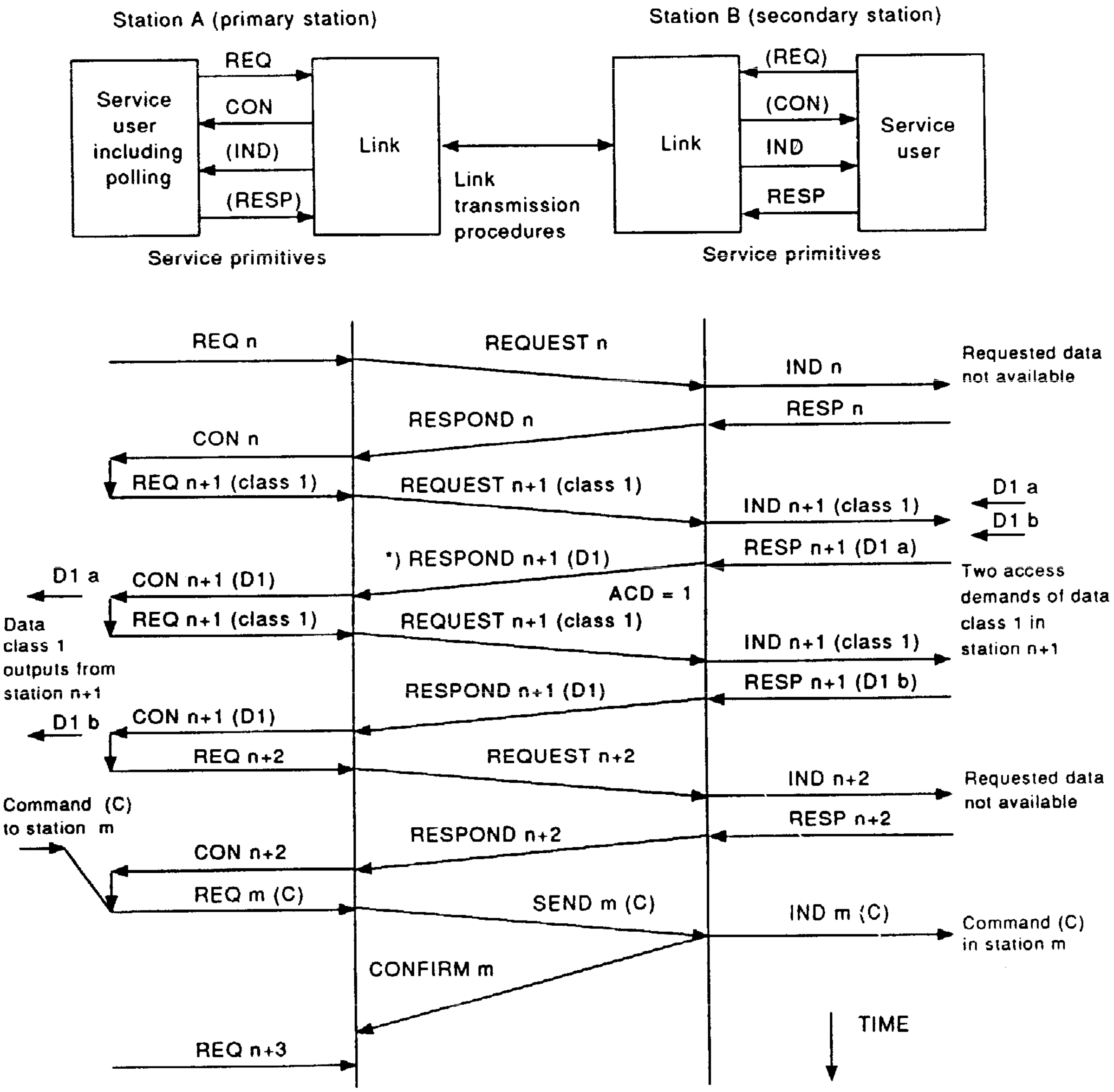
The number of address octets is system dependent (by agreement between vendor and user). Address range with i octets: 0 to $2^{8i} - 1$. The first transmitted address octet contains the least significant address bits.

Broadcast address (message to all stations) = $2^{8i} - 1$.

Group addresses should be defined by agreements between users and vendors.

5.2 *Unbalanced transmission services*

The interaction of service primitives and associated transmission procedures (described in clause 4) for the polling function is shown in figure 2. The example shows the transmission of two events from the secondary station and of a command from the primary station, corresponding with figures 6 and 3.



*) Response from station n+1 with data class 1 and access demand bit = 1.

NOTE - n, n+1, n+2, etc., is a sequence of addresses as defined by the polling procedure.

Figure 2 - Example of the interaction between a polling procedure and an event-initiated transmission

5.3 *Unbalanced transmission procedures*

In figures 3 to 9 a white box represents a correctly received frame. A grey box represents a frame which is not correctly received. An arrow indicates a causal relationship.

5.3.1 *SEND/NO REPLY procedures*

The transmission of a SEND data frame without reply follows the transmission rules described in 4.1.

5.3.2 *Undisturbed SEND/CONFIRM procedures*
Figure 3 shows examples

This procedure is composed of a non-separable sequence of two transmission frames (see figure 3), a SEND data frame transmitted by the primary station, followed by a CONFIRM frame returned by the addressed secondary station.

If the SEND data frame is accepted by the secondary station, it transmits a positive acknowledgement (CONFIRM). The CONFIRM frame may be a single character, as indicated in the top example of figure 3, or a frame with fixed length, particularly if the confirmation is used to inform the primary station on particular states of the secondary station, such as indicating the wish for transmission of data class 1 (see second example [SEND data to secondary station address m] in figure 3).

Note that the positive acknowledgement indicates to the primary station only that the frame was accepted without a detected error and that there was no data overflow condition in the link layer of the addressed receiving station. This does not, however, guarantee the successful execution of the intended command. To protect critical commands against loss, the provision of return information (see IEV 371-02-05) from the application layer is indispensable.

If the SEND data frame is correctly received but is not accepted by the secondary station (e.g. due to an overflow condition), a frame with fixed length "NACK" (negative acknowledgement) is returned and the service user in the primary station is notified correspondingly.

5.3.3 *Disturbed SEND/CONFIRM procedures*
Figure 4 shows examples

If the SEND data frame is corrupted on the transmission path, then there is no response and the primary station repeats the SEND data frame with unchanged frame count bit in the control field of the frame after time out (see first example in figure 4).

If the CONFIRM frame is corrupted (second example in figure 4), then the primary station also repeats the SEND data frame with unchanged frame count bit after time out. The secondary station recognizes the repeated data transmission by the unchanged frame count bit and thus discards the data and transmits the previous CONFIRM frame again.

5.3.4 *Undisturbed REQUEST/RESPOND procedures*
Figures 5, 6 and 7 show examples

Figure 5 shows examples of REQUEST/RESPOND procedures in which the requested data are not available in the addressed station. This procedure is used, for example for polling secondary stations for events or status changes. If no events are registered after a previous corresponding poll, the secondary station returns a negative acknowledgement (NACK). The corresponding RESPOND frame may be a single character frame or a frame with fixed length for indicating special states to the primary station.

In the second polling example of figure 6 it is assumed that the primary station requests data class 1 from secondary station n+1 and that the amount of data class 1 waiting for transmission exceeds a specified limit of the RESPOND frame. In this case the secondary station indicates the wish for further data class 1 transmission in the control field. If the primary station accepts the continuation it sends a further REQUEST frame to the same secondary station with an altered frame count bit (in contrast, the repeated REQUEST frame to the same secondary station contains the unaltered frame count bit on receiving no response or a corrupted response, see figures 8 and 9).

In figure 7 the primary station polls data class 2 from station n. The secondary station returns the requested data and indicates in the control field the demand for data class 1 transmission. The primary station proceeds by polling the same station for data class 1 with an altered frame count bit and then continues with polling of data class 2 from the next secondary station.

5.3.5 *Disturbed REQUEST/RESPOND procedures*
Figures 8 and 9 show examples

Figure 8 shows the consequence of a disturbed REQUEST frame: since the disturbed REQUEST frame causes no response, the primary station repeats the REQUEST frame with an unaltered frame count bit to the same secondary station after time out.

Figure 9 shows the consequence of a disturbed RESPOND frame: the primary station repeats the REQUEST frame with an unaltered frame count bit to the same secondary station after time out. The secondary station, which is obliged to keep a copy of the previously transmitted RESPOND frame, recognizes the REQUEST for a repeated frame transmission by the unaltered frame count bit and transmits the previously transmitted response again.

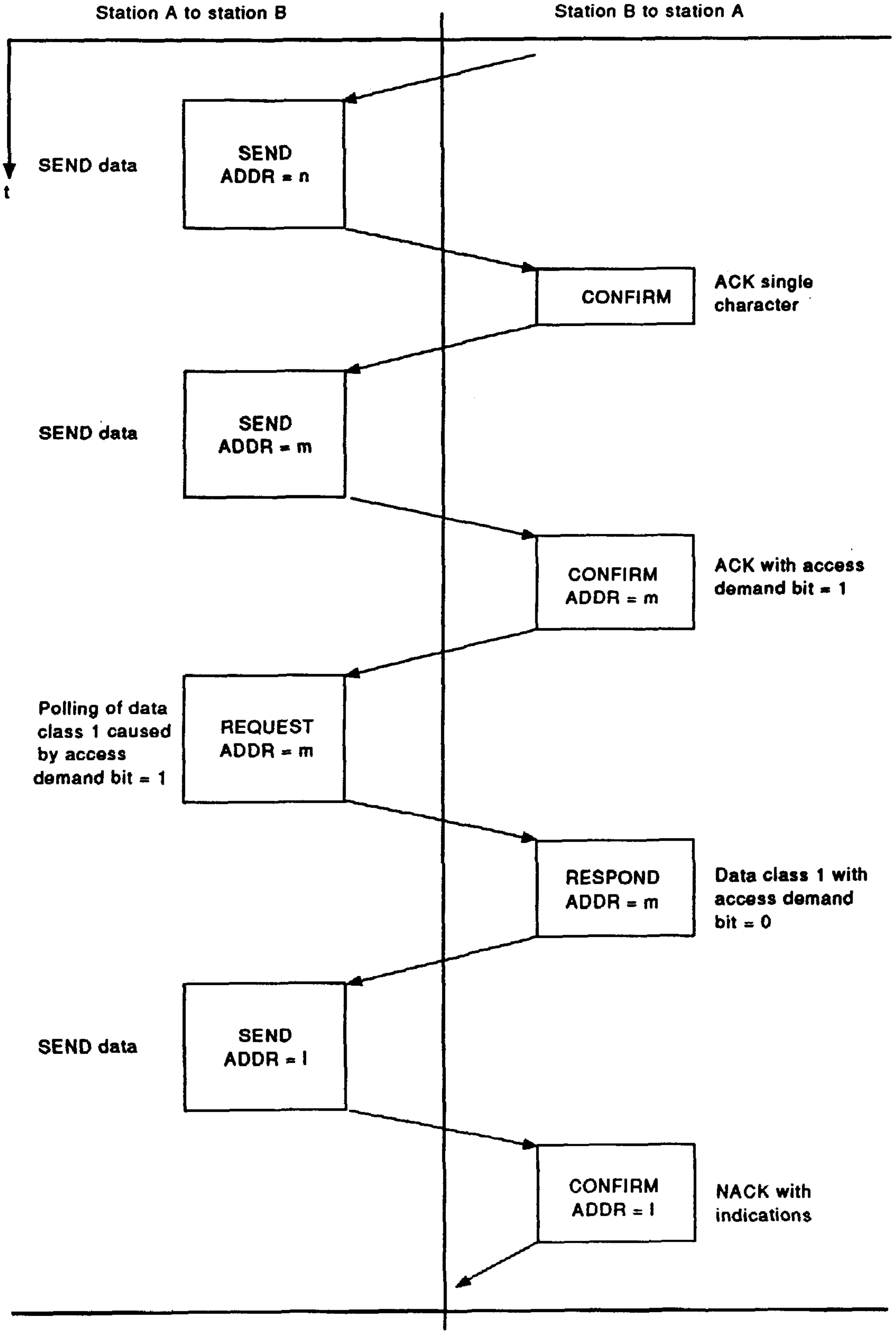


Figure 3 – Unbalanced transmission procedures, undisturbed SEND/CONFIRM procedures

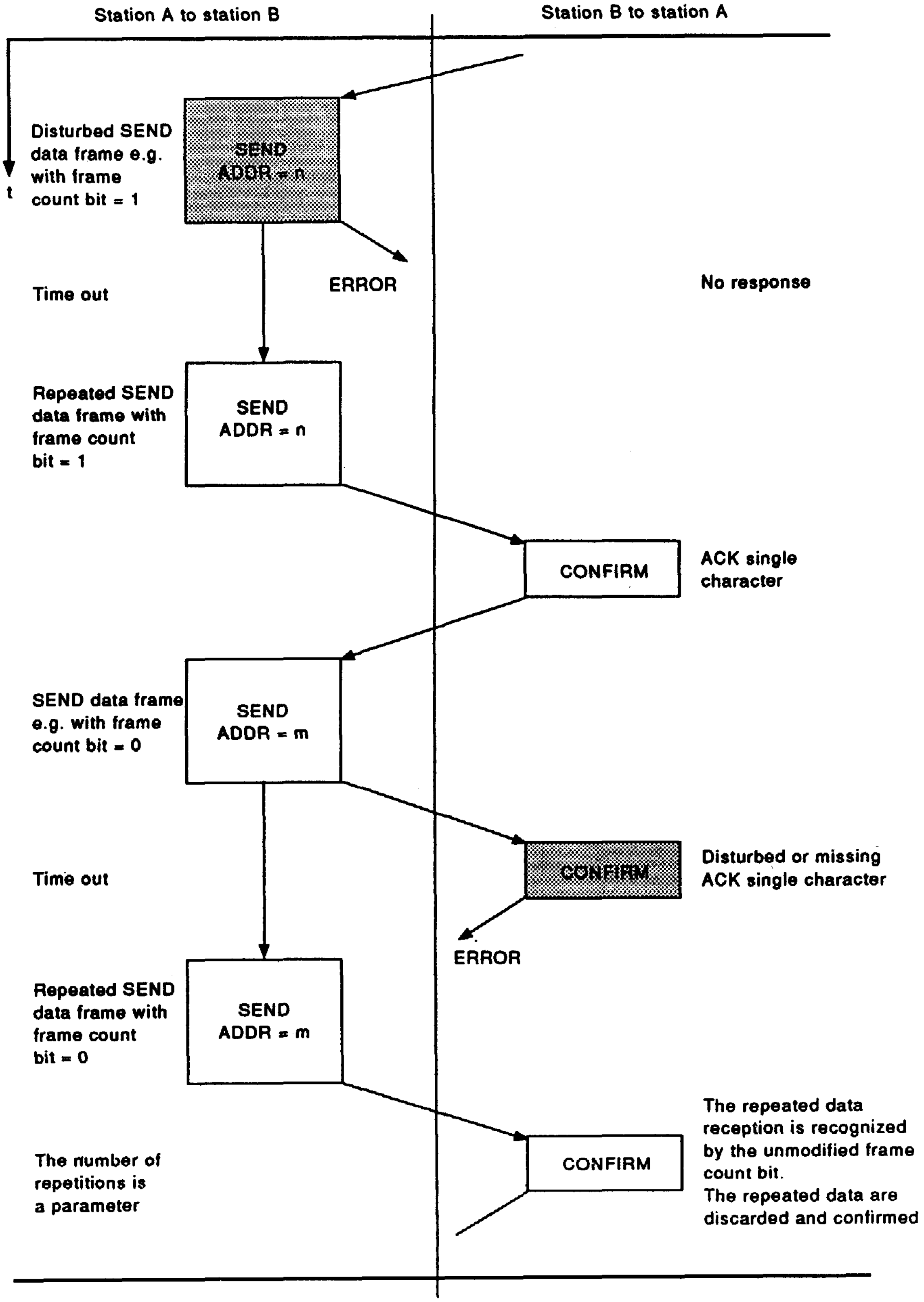

Station A to station B
Station B to station A
t
Disturbed SEND data frame e.g. with frame count bit = 1
SEND ADDR = n
ERROR
Time out
No response
Repeated SEND data frame with frame count bit = 1
SEND ADDR = n
CONFIRM
ACK single character
SEND data frame e.g. with frame count bit = 0
SEND ADDR = m
Time out
CONFIRM
Disturbed or missing ACK single character
ERROR
Repeated SEND data frame with frame count bit = 0
SEND ADDR = m
CONFIRM
The number of repetitions is a parameter
The repeated data reception is recognized by the unmodified frame count bit.
The repeated data are discarded and confirmed

Figure 4 – Unbalanced transmission procedures, disturbed SEND/CONFIRM procedures

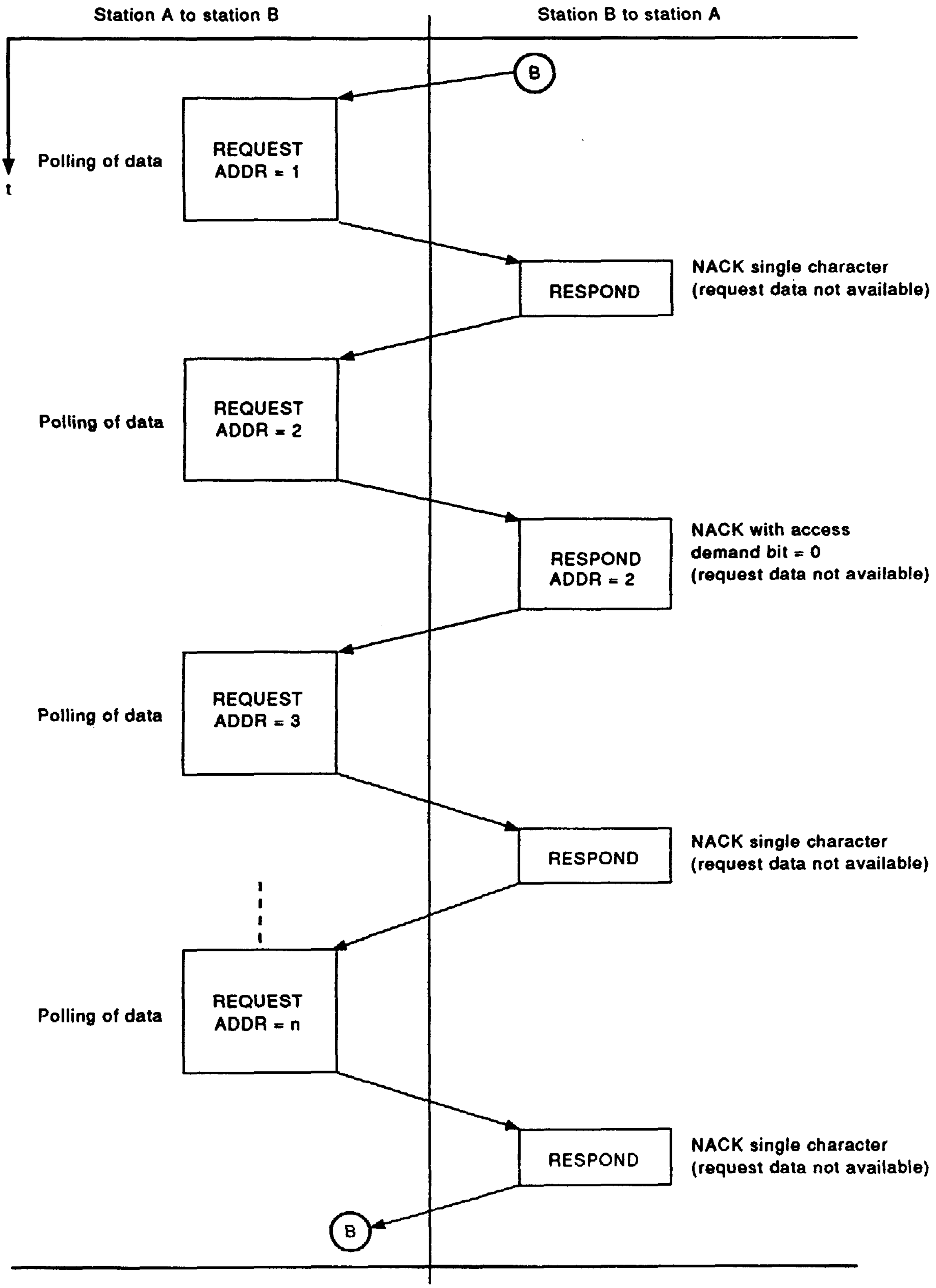

Station A to station B
Station B to station A
B
t
Polling of data
REQUEST ADDR = 1
RESPOND
NACK single character (request data not available)
Polling of data
REQUEST ADDR = 2
RESPOND ADDR = 2
NACK with access demand bit = 0 (request data not available)
Polling of data
REQUEST ADDR = 3
RESPOND
NACK single character (request data not available)
Polling of data
REQUEST ADDR = n
RESPOND
NACK single character (request data not available)
B

Figure 5 – Unbalanced transmission procedures, undisturbed REQUEST/RESPOND procedures

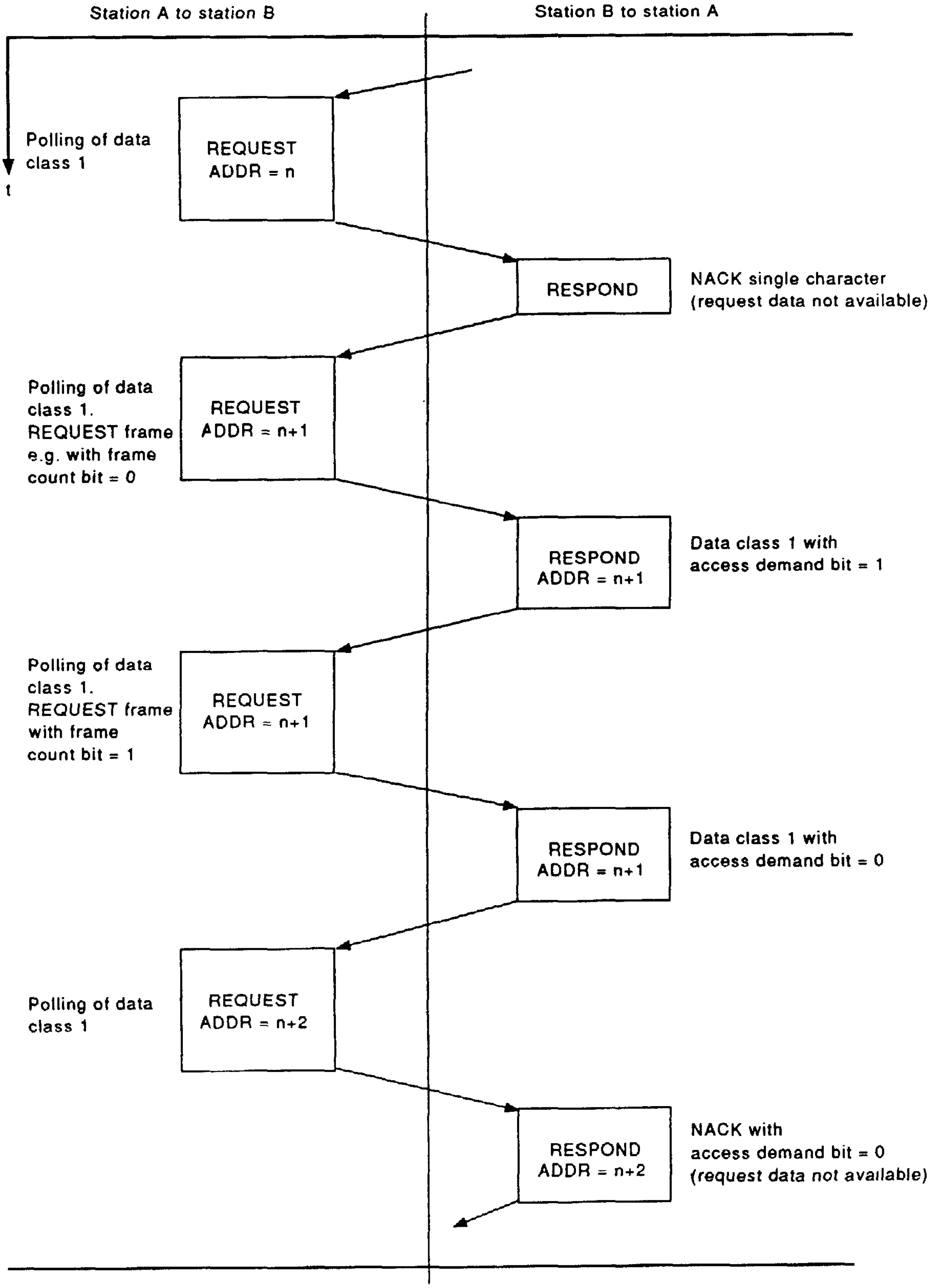

Station A to station B
Station B to station A
t
Polling of data class 1
REQUEST ADDR = n
RESPOND
NACK single character (request data not available)
Polling of data class 1. REQUEST frame e.g. with frame count bit = 0
REQUEST ADDR = n+1
RESPOND ADDR = n+1
Data class 1 with access demand bit = 1
Polling of data class 1. REQUEST frame with frame count bit = 1
REQUEST ADDR = n+1
RESPOND ADDR = n+1
Data class 1 with access demand bit = 0
Polling of data class 1
REQUEST ADDR = n+2
RESPOND ADDR = n+2
NACK with access demand bit = 0 (request data not available)

Figure 6 – Unbalanced transmission procedures,
undisturbed REQUEST/RESPOND procedures

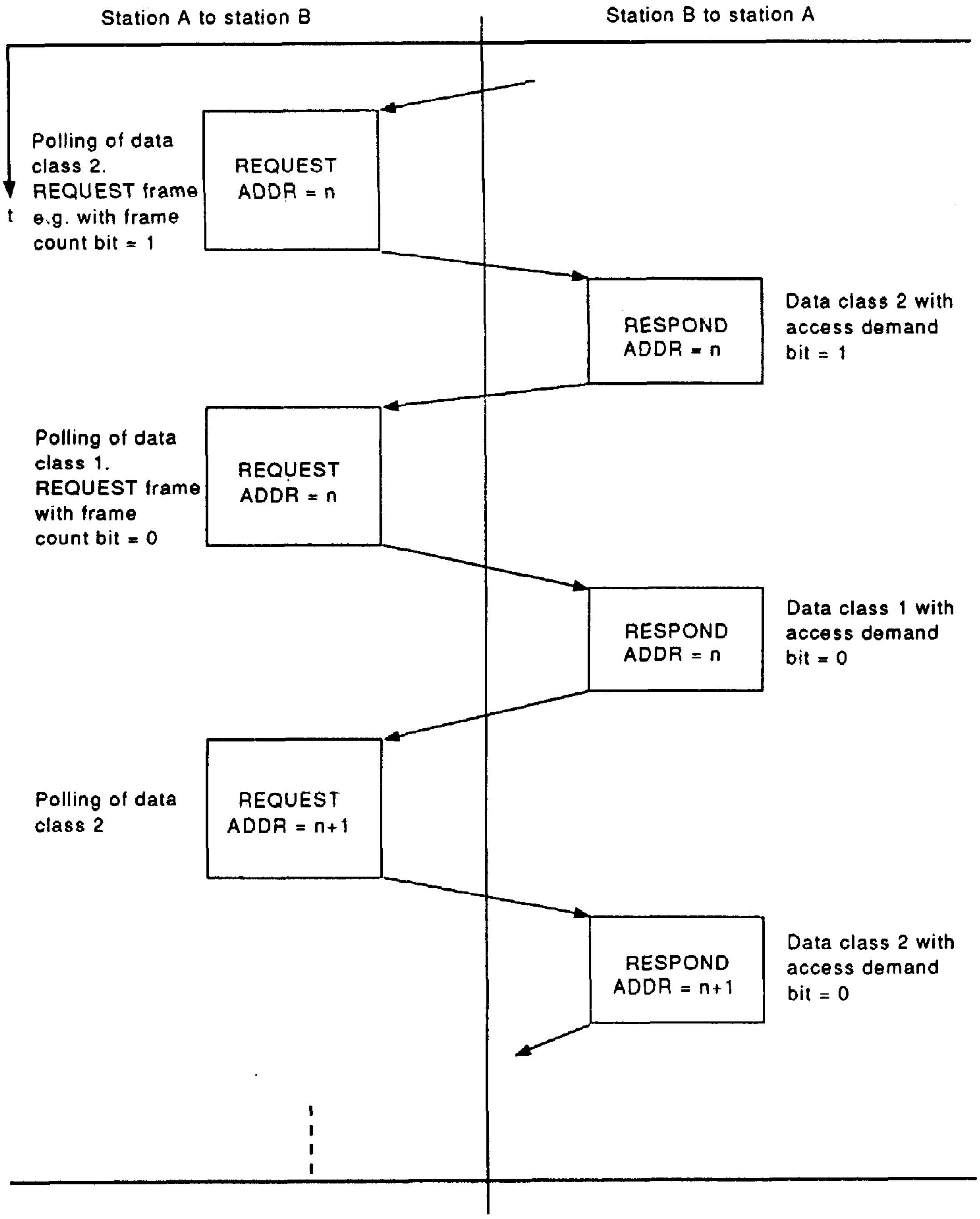

Station A to station B
Station B to station A
t
Polling of data class 2. REQUEST frame e.g. with frame count bit = 1
REQUEST ADDR = n
RESPOND ADDR = n
Data class 2 with access demand bit = 1
Polling of data class 1. REQUEST frame with frame count bit = 0
REQUEST ADDR = n
RESPOND ADDR = n
Data class 1 with access demand bit = 0
Polling of data class 2
REQUEST ADDR = n+1
RESPOND ADDR = n+1
Data class 2 with access demand bit = 0

Figure 7 – Unbalanced transmission procedures, undisturbed REQUEST/RESPOND procedures

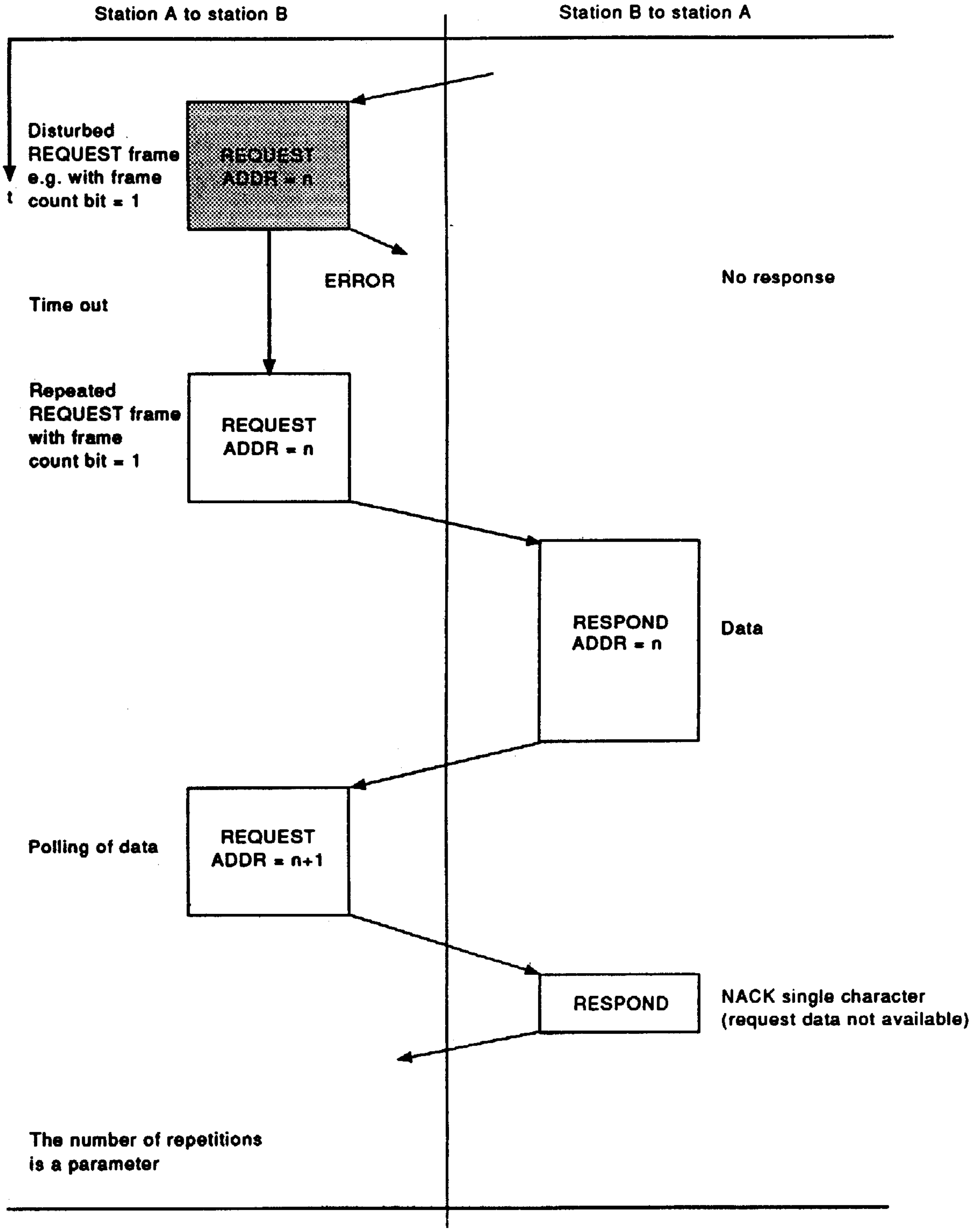

Station A to station B
Station B to station A
Disturbed REQUEST frame e.g. with frame count bit = 1
t
REQUEST ADDR = n
ERROR
No response
Time out
Repeated REQUEST frame with frame count bit = 1
REQUEST ADDR = n
RESPOND ADDR = n
Data
Polling of data
REQUEST ADDR = n+1
RESPOND
NACK single character (request data not available)
The number of repetitions is a parameter

Figure 8 – Unbalanced REQUEST/RESPOND transmission procedures, disturbed REQUEST frame

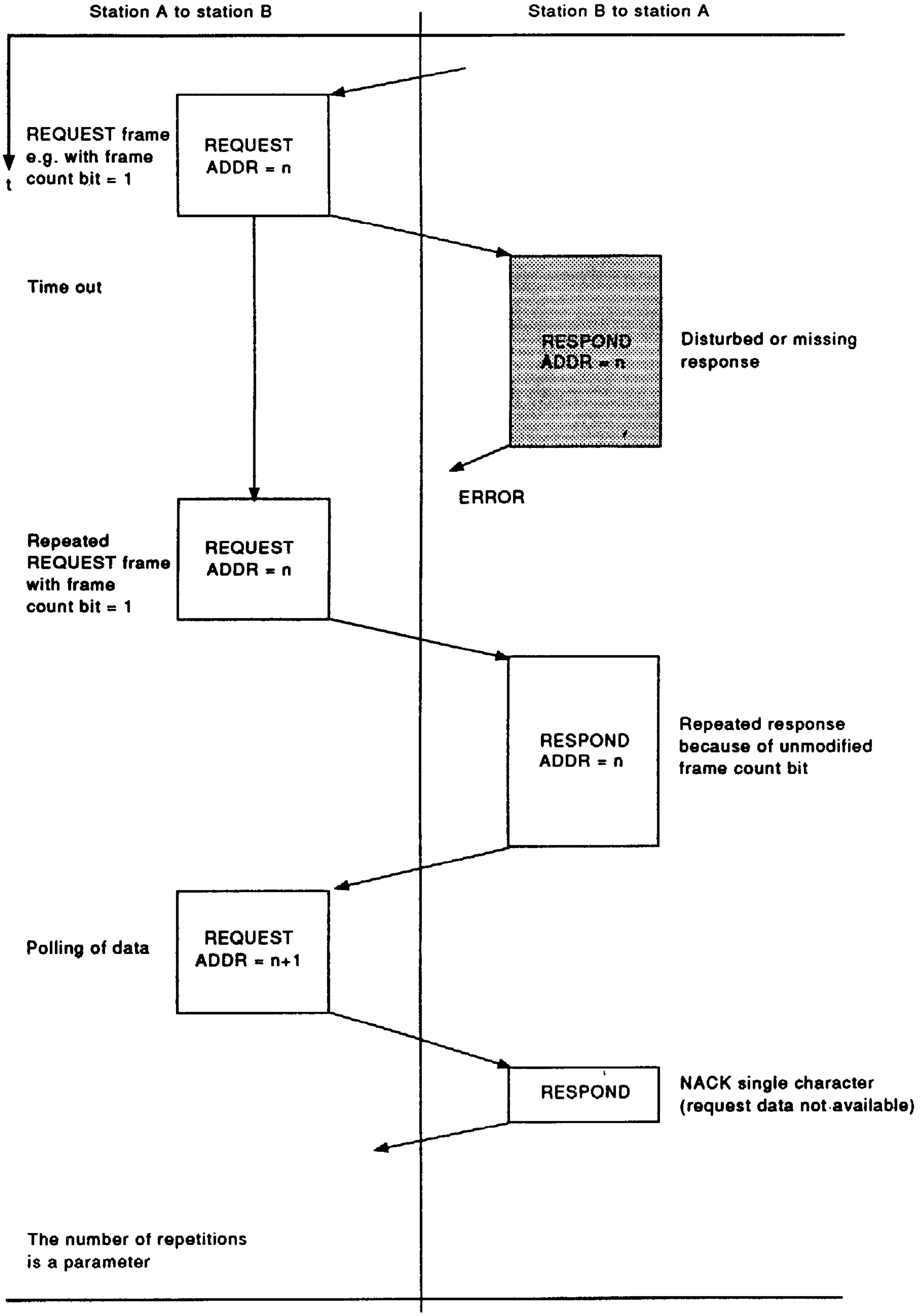

Station A to station B
Station B to station A
t
REQUEST frame e.g. with frame count bit = 1
REQUEST ADDR = n
Time out
RESPOND ADDR = n
Disturbed or missing response
ERROR
Repeated REQUEST frame with frame count bit = 1
REQUEST ADDR = n
RESPOND ADDR = n
Repeated response because of unmodified frame count bit
Polling of data
REQUEST ADDR = n+1
RESPOND
NACK single character (request data not available)
The number of repetitions is a parameter

Figure 9 – Unbalanced REQUEST/RESPOND transmission procedures, disturbed RESPOND frame

6 Balanced transmission

If balanced transmission procedures are used, each station may initiate message transfers. Because such stations may act simultaneously as primary and secondary stations, they are called combined stations. In the following, the combined station is called either primary or secondary station according to its described functions.

The balanced transmission procedure is restricted to point-to-point (see 4.4.1 of IEC 870-1-1 and IEV 371-06-06) and multiple point-to-point configurations (see 4.4.2 of IEC 870-1-1 and IEV 371-06-07).

6.1 *Specification of length, control, and address fields*

6.1.1 *Length field*

The length field is as defined in 6.2.4 of IEC 870-5-1 and also in this section in 3.1 to 3.4.

6.1.2 *Control field*

The control field contains information that characterizes the direction of the message, the type of the service provided and supports control functions for suppressing losses or duplications of messages.

<table>
<tr><td></td><td>MSB</td><td></td><td></td><td></td><td></td><td></td><td></td><td>LSB</td><td></td></tr>
<tr><td rowspan="2">Control field</td><td rowspan="2">DIR</td><td rowspan="2">1
PRM
0</td><td>FCB</td><td>FCV</td><td>2^3</td><td>2^2</td><td>2^1</td><td>2^0</td><td>Primary to secondary</td></tr>
<tr><td>RES</td><td>DFC</td><td colspan="4">Function</td><td>Secondary to primary</td></tr>
<tr><td>Bit:</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td></td></tr>
</table>

RES: reserved

DIR: physical transmission direction: 1 = station A to station B
0 = station B to station A

FCB: frame count bit: 0,1 = alternating bit for successive SEND/CONFIRM or REQUEST/RESPOND services per station.

The frame count bit is used for suppressing losses and duplications of information transfers. The primary station alternates the FCB bit for each new SEND/CONFIRM or REQUEST/RESPOND transmission service directed to the same secondary station. Thus the primary station keeps a copy of the frame count bit per secondary station. If an expected reply is timed out (missing) or garbled, then the same SEND/CONFIRM or REQUEST/RESPOND service is repeated with the same frame count bit.

In case of reset commands (see table 3) the FCB bit is always zero, and upon receipt of these commands the secondary station will always be set to expect the next frame primary to secondary with FCV = valid (FCV=1) to have the opposite setting of FCB, i.e. FCB equal to one.

FCV: frame count bit valid: 0 = alternating function of FCB bit is invalid;
1 = alternating function of FCB bit is valid.

SEND/NO REPLY services, broadcast messages and other transmission services that ignore the deletion of duplication or loss of information output do not alternate the FCB bit and indicate this by a cleared FCV bit.

DFC: data flow control: 0 = further messages are acceptable;
1 = further messages may cause data overflow.

Secondary (responding) stations indicate to the message initiating (primary) station that an immediate succession of a further message may cause a buffer overflow.

PRM: primary message: 0 = message from secondary (responding) station;
1 = message from primary (initiating) station.

Table 3 – Balanced transmission, function codes of control field in messages sent from primary (PRM = 1)

Function code No.	Frame type	Service function	FCV
0	SEND/CONFIRM expected	Reset of remote link	0
1	SEND/CONFIRM expected	Reset of user process	0
2	SEND/CONFIRM expected	Test function for link	1
3	SEND/CONFIRM expected	User data	1
4	SEND/NO REPLY expected	User data	0
5		Reserved	–
6 - 7		Reserved for special use by agreement	–
8		Reserved for unbalanced transmission procedure	–
9	REQUEST /RESPOND expected	Request status of link	0
10		Reserved for unbalanced transmission procedure	–
11		Reserved for unbalanced transmission procedure	–
12 - 13		Reserved	–
14 - 15		Reserved for special use by agreement	–

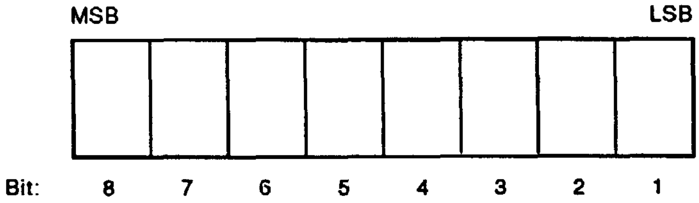
Table 4 – Balanced transmission, function codes of control field in messages sent from secondary (PRM = 0)

Function code No.	Frame type	Service function
0	CONFIRM	ACK: positive acknowledgement
1	CONFIRM	NACK: message not accepted, link busy
2 - 5		Reserved
6 - 7		Reserved for special use by agreement
8		Reserved for unbalanced transmission procedure
9		Reserved for unbalanced transmission procedure
10		Reserved
11	RESPOND	Status of link
12		Reserved
13		Reserved for special use by agreement
14	–	Link service not functioning
15	–	Link service not implemented

6.1.3 *Address field*

If it is used, the address field specifies the station address. The address field may be omitted.

Address field:



LSB: Least significant bit
MSB: Most significant bit

The number of address octets is system dependent (by agreement between vendor and user). Address range with i octets: 0 to $2^{8i} - 1$. The first transmitted address octet contains the least significant address bits.

6.2 *Balanced transmission services*

The interaction of service primitives and associated transmission procedures (described in clause 4) is shown in figure 10. The example shows the transmission of messages in both directions simultaneously, corresponding with figure 11.

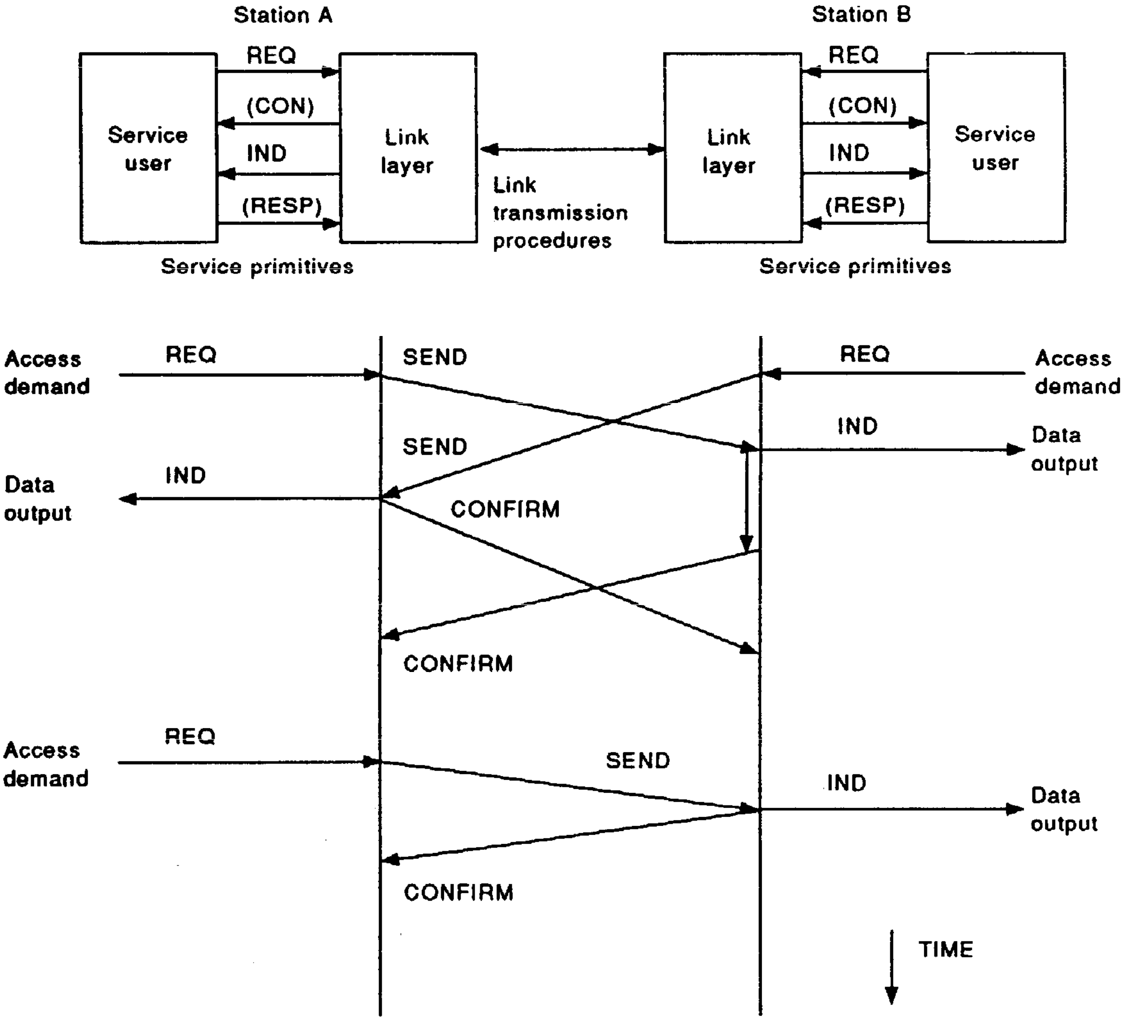


Figure 10 – Example of the interaction of service primitives and transmission procedures in a balanced system

6.3 *Balanced transmission procedures*

Balanced transmission procedures are restricted to point-to-point configurations equipped with a duplex channel operation. In these applications, both stations involved have equal access rights, i.e. there is no master slave relation assigned to the stations.

In figures 11 to 16, a white box represents a correctly received frame. A grey box represents a frame which is not correctly received. An arrow indicates a causal relationship.

6.3.1 *SEND/NO REPLY procedures*

Both stations may use the duplex channel independently and simultaneously for message transmission by observing the transmission rules stated in 4.1.

6.3.2 *Undisturbed SEND/CONFIRM procedures*

Figure 11 shows examples

The transmission of SEND data frames may be initiated independently from both stations; however, the receipt of the associated CONFIRM frame is the condition for continuing with a following SEND data procedure

6.3.3 *Undisturbed procedures with data flow control*

Figure 12 shows examples

The secondary station indicates with DFC bit = 1 to the primary station that further messages may cause a buffer overflow. In this case, the primary station may transmit periodically repeated requests for the status of the link, until the secondary station indicates by DFC bit = 0 that further messages are acceptable.

6.3.4 *Disturbed SEND/CONFIRM procedures*

Figures 13, 14, 15 and 16 show examples

If the SEND data frame is disturbed and thus no CONFIRM frame is received within the time out, the SEND data frame is repeated with the unaltered frame count bit (see figure 13). The same procedure is performed if the CONFIRM frame is disturbed (see figure 15).

If the SEND data frame is disturbed, the receiving station waits until it has detected a specified interval of line idle before accepting another frame. If a CONFIRM frame occurs during this interval, it will be ignored by the receiving station. In this case, the SEND data frames of each station are repeated with the unaltered frame count bit (see figure 14).

Figure 16 shows the error recovery procedure if a CONFIRM frame and a subsequent SEND data frame transmission from one station are disturbed.

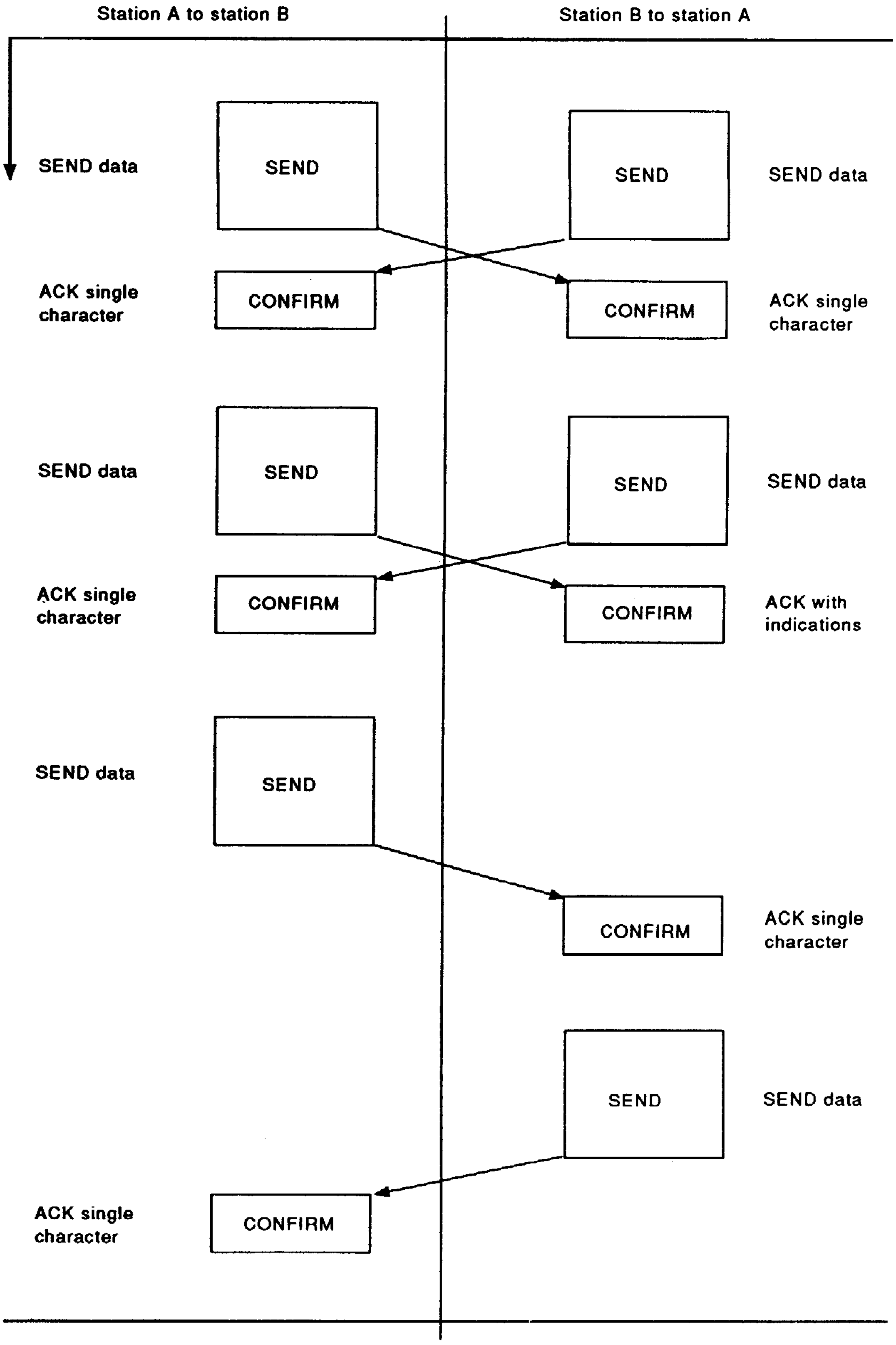


Figure 11 – Balanced transmission procedures, undisturbed SEND/CONFIRM procedures

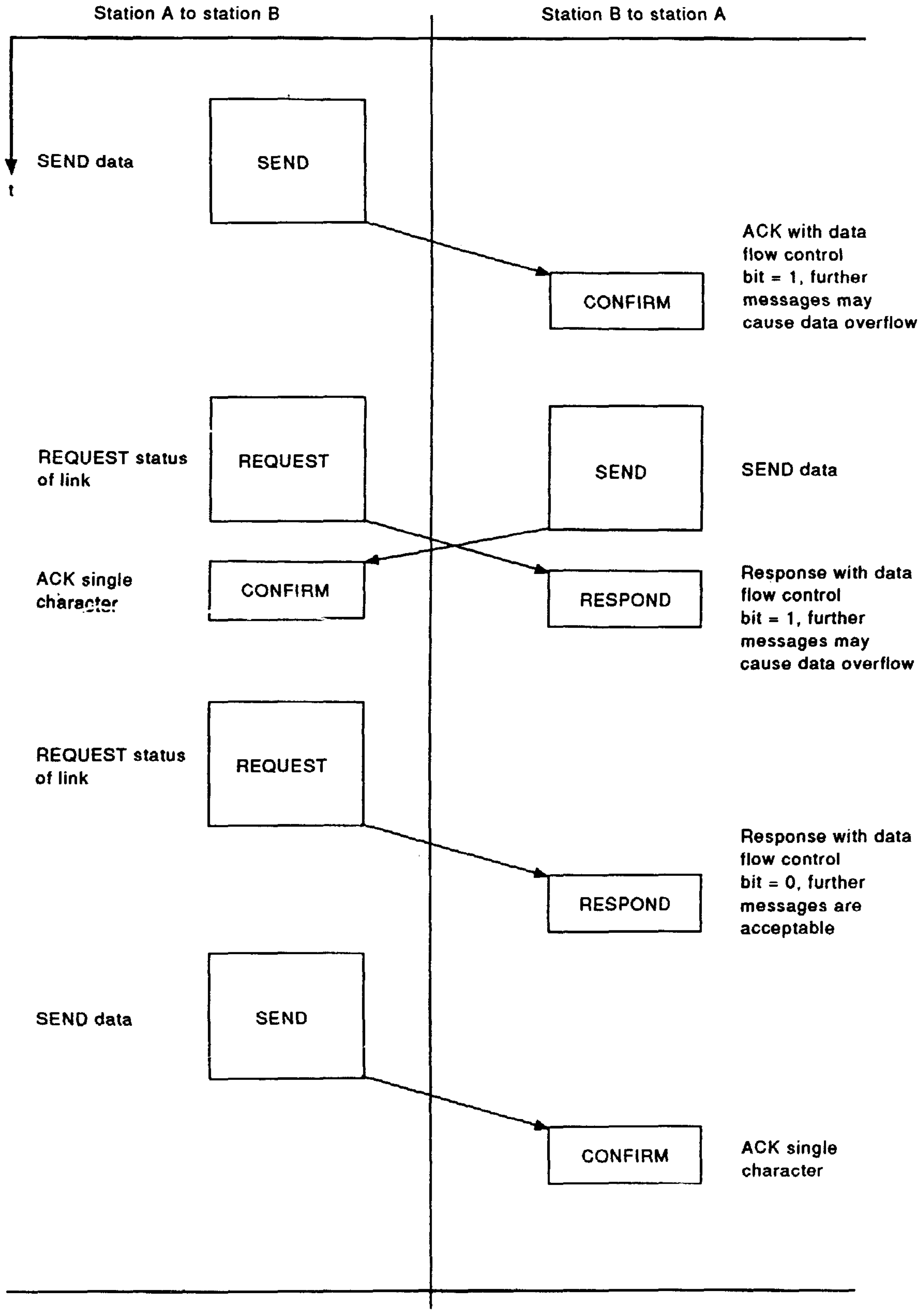

Station A to station B
Station B to station A
t
SEND data
SEND
CONFIRM
ACK with data flow control bit = 1, further messages may cause data overflow
REQUEST status of link
REQUEST
SEND
SEND data
ACK single character
CONFIRM
RESPOND
Response with data flow control bit = 1, further messages may cause data overflow
REQUEST status of link
REQUEST
RESPOND
Response with data flow control bit = 0, further messages are acceptable
SEND data
SEND
CONFIRM
ACK single character

Figure 12 – Balanced transmission procedures, data flow control

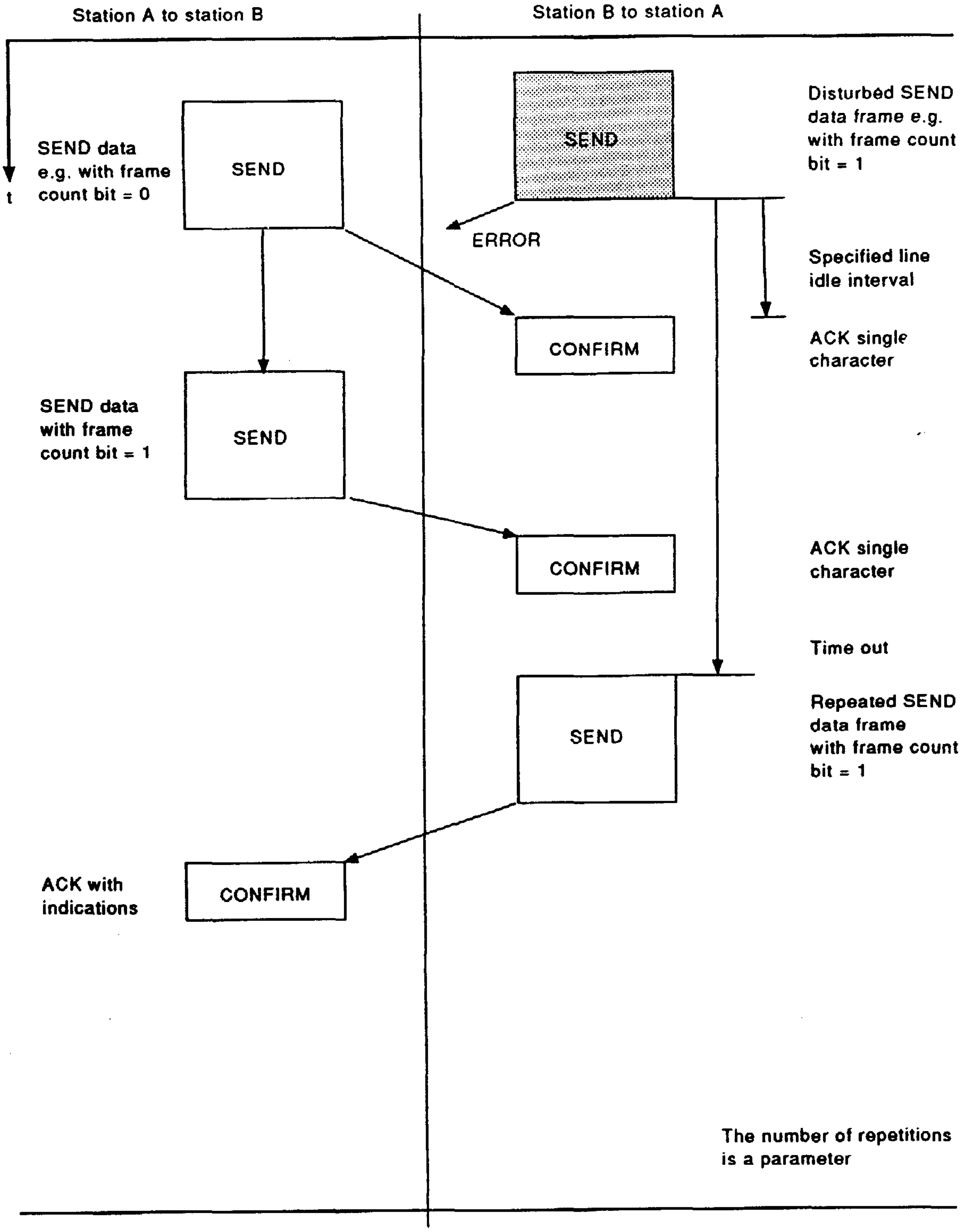


Figure 13 – Balanced transmission procedures, disturbed SEND frame

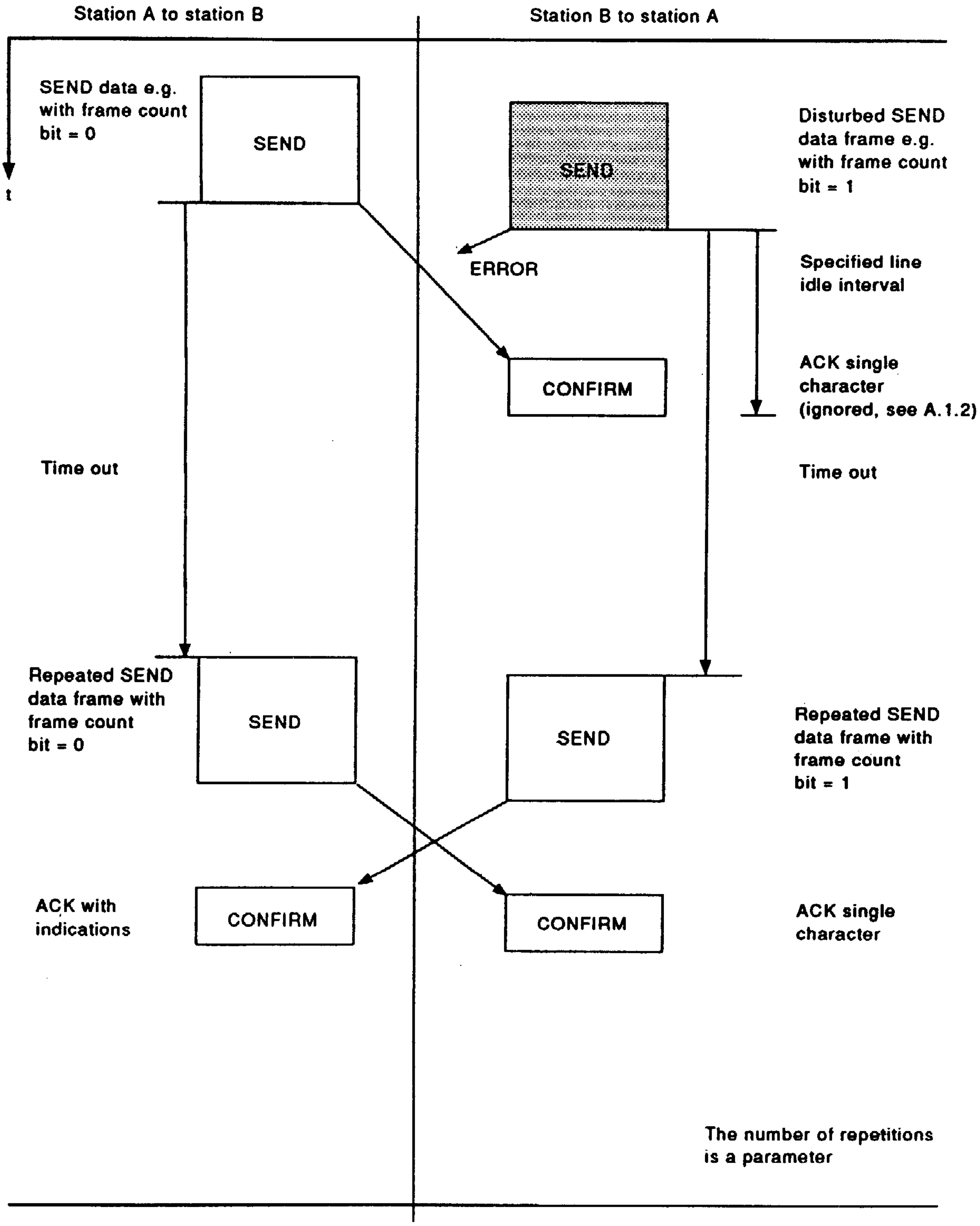

Station A to station B
Station B to station A
t
SEND data e.g. with frame count bit = 0
SEND
SEND
Disturbed SEND data frame e.g. with frame count bit = 1
ERROR
Specified line idle interval
CONFIRM
ACK single character (ignored, see A.1.2)
Time out
Time out
Repeated SEND data frame with frame count bit = 0
SEND
SEND
Repeated SEND data frame with frame count bit = 1
ACK with indications
CONFIRM
CONFIRM
ACK single character
The number of repetitions is a parameter

Figure 14 – Balanced transmission procedures, disturbed SEND and ignored CONFIRM frame

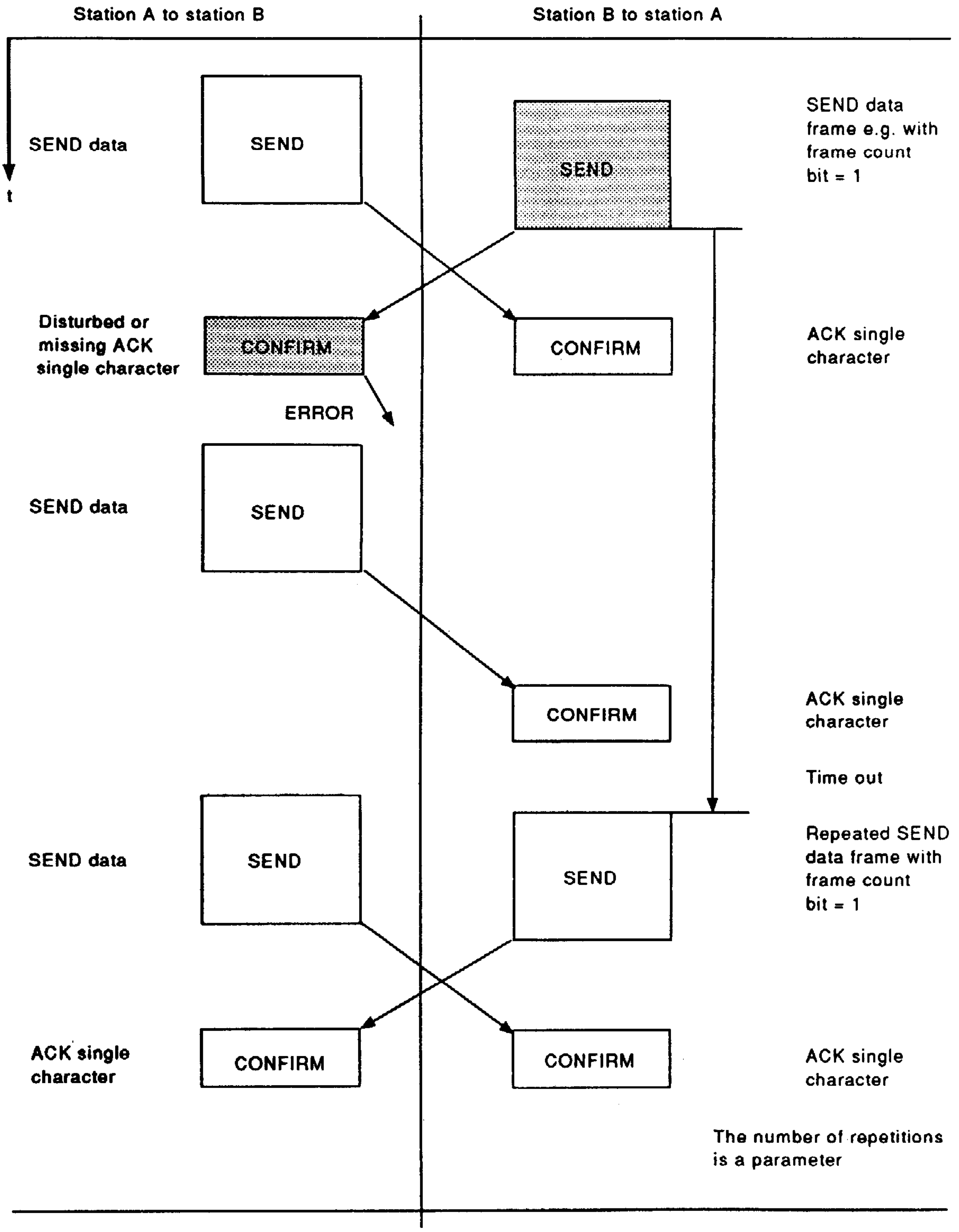


Figure 15 – Balanced transmission procedures, disturbed CONFIRM frame

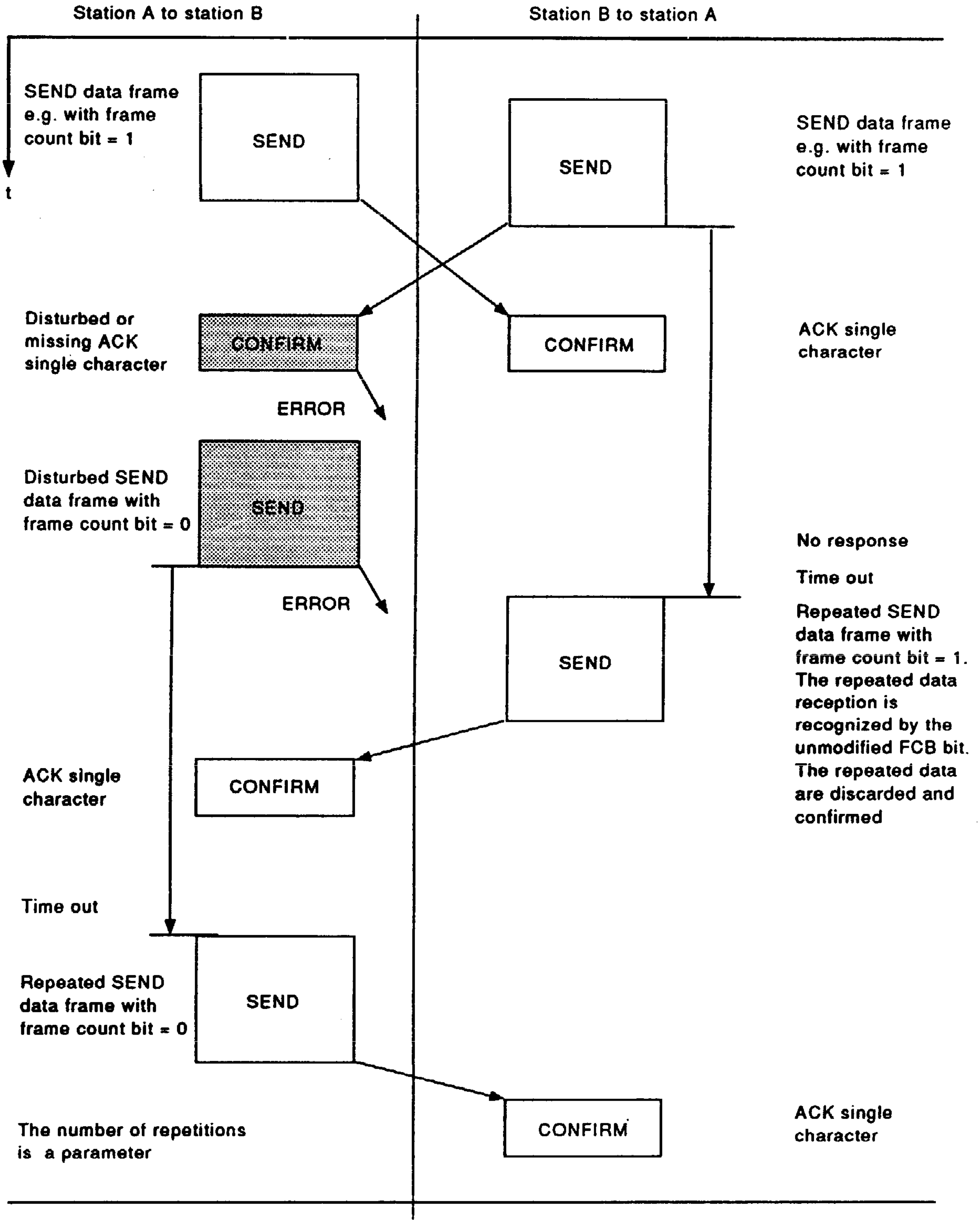

Station A to station B
Station B to station A
t
SEND data frame e.g. with frame count bit = 1
SEND
SEND
SEND data frame e.g. with frame count bit = 1
Disturbed or missing ACK single character
CONFIRM
CONFIRM
ACK single character
ERROR
Disturbed SEND data frame with frame count bit = 0
SEND
No response
Time out
ERROR
SEND
Repeated SEND data frame with frame count bit = 1. The repeated data reception is recognized by the unmodified FCB bit. The repeated data are discarded and confirmed
ACK single character
CONFIRM
Time out
Repeated SEND data frame with frame count bit = 0
SEND
The number of repetitions is a parameter
CONFIRM
ACK single character

Figure 16 – Balanced transmission procedures, disturbed channel in one direction

Annex A
(normative)

Time out interval for repeated frame transmission

In the case of a correctly acknowledged transmission, the primary station may transmit its next frame immediately. However, REQUEST frames or SEND frames that expect immediate CONFIRM frames are repeated if the expected RESPOND (or CONFIRM) frames are not detected.

The duration of the time out interval for the repeated frame transmission that starts after the transmission of the frame in the primary station depends on system specific parameters.

The calculation of the time out interval for unbalanced (figures A.1, A.2) and balanced (figures A.3, A.4) procedures is based on worst-case conditions. It does not depend on information content of frames.

A.1 Unbalanced transmission procedures

NOTE - In this subclause and in A.2 upper case T refers to a specified parameter and lower case t refers to an observed variable.

- Disturbed primary frame, case 1 (see figure A.1).

The secondary station B that detects a disturbed frame requires a minimum time T_{IB} of line idle before it is ready to receive a new frame. The required minimum number of line idle bits that constitutes the time interval T_{IB} is specified in 6.2.4 of IEC 870-5-1 for the different transmission frame formats. In each case the number of line idle bits is specified in such a way that this sequence never occurs in a frame (even allowing for 3 bit errors). This means that the time out interval T_O must fulfill the condition:

$$T_O > T_{IB}$$

- Disturbed primary frame, case 2 (see figure A.1).

If an undisturbed frame is received in the secondary station, then the RESPOND frame (or CONFIRM frame) is received in the primary station A after a loop delay, that is composed of the following time intervals:

$$t_{LD} = t_{DAB} + t_R + t_{DBA}$$

where

t_{LD} is the loop delay;

t_{DAB} is the signal delay time for data from station A to station B;

t_R is the reaction time of the station B to reply to requests;

t_{DBA} is the signal delay time for data from station B to station A .

This means that the time out interval must fulfill the condition:

$$T_O > t_{LD}$$

– Disturbed secondary frame, case 1: maximum time out interval (see figure A.2).

If a constant time out interval is used, i.e. a time out interval that does not depend on the actual length of the response frame, then this interval must fulfill the condition:

$$T_O > t_{LD} + T_{LBA}$$

where

T_{LBA} is the longest frame from secondary to primary station.

In systems with wide dynamic ranges of the length of responding frames, this condition of the time out interval may be very long. In these systems, it may be preferred to adjust the time out interval T_O to the actual length of the responding frame.

– Disturbed secondary frame, case 2: matched time out interval (see figure A.2).

If the time out interval is matched to the actual frame length of the responding frame, then the bit stream of the disturbed frame from the secondary station is supervised by the primary station until a line idle interval T_{IA} is detected. This interval is specified in IEC 870-5-1 for the different transmission frame formats. The time out condition T_m is therefore given by:

$$T_m > t_{LD} + t_{FBA} + T_{IA}$$

where

t_{FBA} is the actual length of the frame from station B to station A.

T_{IA} is the prescribed line idle interval after the detection of an error in station A.

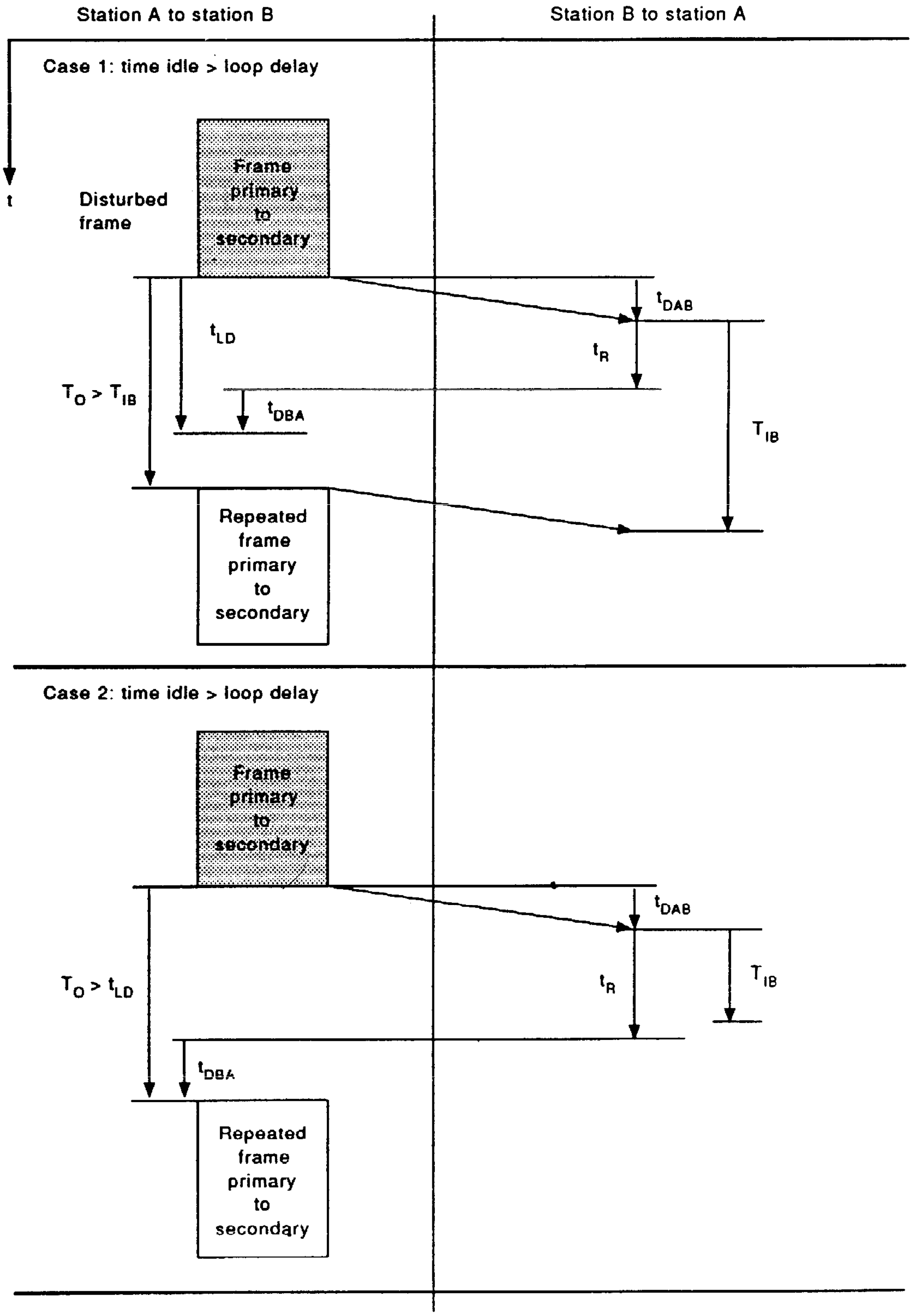

Station A to station B
Station B to station A
Case 1: time idle > loop delay
t
Disturbed frame
Frame primary to secondary
tDAB
tLD
tR
TO > TIB
tDBA
TIB
Repeated frame primary to secondary
Case 2: time idle > loop delay
Frame primary to secondary
tDAB
TO > tLD
tR
TIB
tDBA
Repeated frame primary to secondary

Figure A.1 – Unbalanced transmission procedures, disturbed primary frame

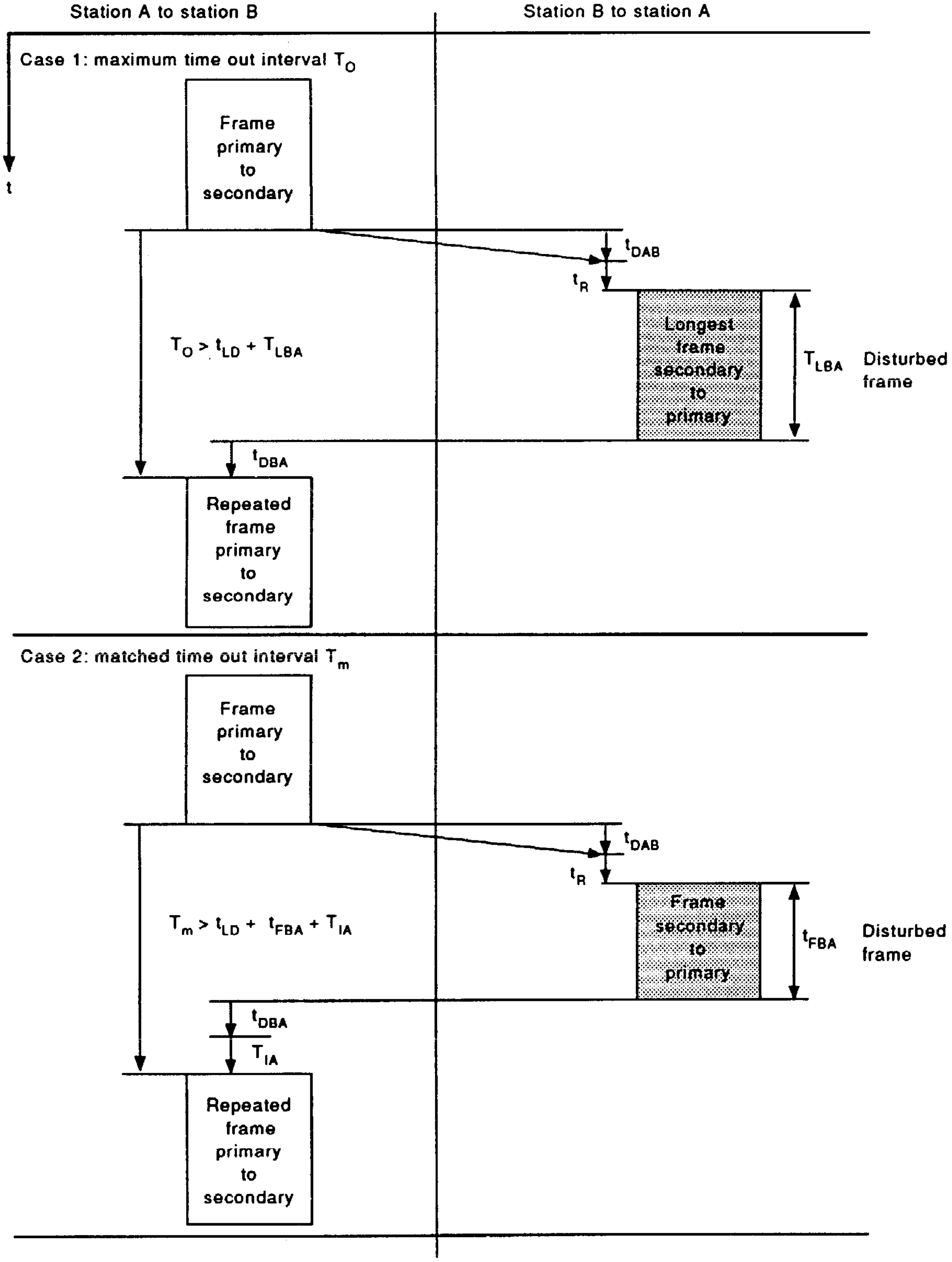

Station A to station B
Station B to station A
Case 1: maximum time out interval T_O
t
Frame primary to secondary
t_{DAB}
t_R
$T_O > t_{LD} + T_{LBA}$
Longest frame secondary to primary
T_{LBA}
Disturbed frame
t_{DBA}
Repeated frame primary to secondary
Case 2: matched time out interval T_m
Frame primary to secondary
t_{DAB}
t_R
$T_m > t_{LD} + t_{FBA} + T_{IA}$
Frame secondary to primary
t_{FBA}
Disturbed frame
t_{DBA}
T_{IA}
Repeated frame primary to secondary

Figure A.2 – Unbalanced transmission procedures, disturbed secondary frame

A.2 Balanced transmission procedures

In balanced transmission procedures the two communicating stations may transmit frames simultaneously. Therefore the following maximum time out intervals may occur:

- Disturbed primary frame, case 1: maximum time out interval (see figure A.3).

If the primary frame transmitted by station A is disturbed, the maximum time out interval arises if station B begins to transmit its longest primary frame just at (or shortly before) the beginning of the expected secondary frame from station B. The resulting condition for the time out interval T_O is:

$$T_O > t_{DAB} + T_{LPSBA} + t_{GB} + t_{DBA}$$

where

T_O	is the maximum time out interval;
t_{DAB}	is the signal delay from station A to station B;
T_{LPSBA}	is the longest secondary frame from station B;
t_{GB}	is the gap between two successive transmission frames in station B;
t_{DBA}	is the signal delay from station B to station A.

- Disturbed primary frame, case 2: matched time out interval T_m (see figure A.3).

If the time out interval is matched to the actual frame length of disturbed frames received after the transmission of the primary frame, the time out interval T_m is given by:

$$T_m > t_{DAB} + T_{FPSBA} + t_{DBA} + T_{IA}$$

where

T_{FPSBA}	is the actual primary frame length from station B;
T_{IA}	is the prescribed line idle interval after detection of an error in station A.

- Disturbed secondary frame, case 1: maximum time out interval (see figure A.4).

If station A receives a disturbed frame after transmitting a primary frame, the maximum time out interval arises if station B sends a disturbed longest secondary frame and a longest primary frame follows immediately. In this case station A will not only discard that disturbed secondary frame but also the succeeding primary frame, since the interval between two successive frames in station B is (in general) shorter than the interval T_{IA} that is required to resynchronize a new frame. The resulting condition for the time out interval T_O is:

$$T_O > t_{LDA} + T_{LSPBA} + t_{GB} + T_{LPSBA}$$

where

t_{LDA}	is the loop delay observed by station A;
T_{LSPBA}	is the longest primary frame from station B.

- Disturbed secondary frame, case 2: matched time out interval T_m (see figure A.4).

If the time out interval is matched to the length of frames that are received with errors detected after the transmission of the primary frame, then the time out interval may extend to:

$$T_m > t_{LDA} + T_{FSPBA} + t_{GB} + T_{FPSBA} + T_{IA}$$

where

T_m is the time out interval matched to the received secondary frame;

T_{FSPBA} is the actual secondary frame length from station B.

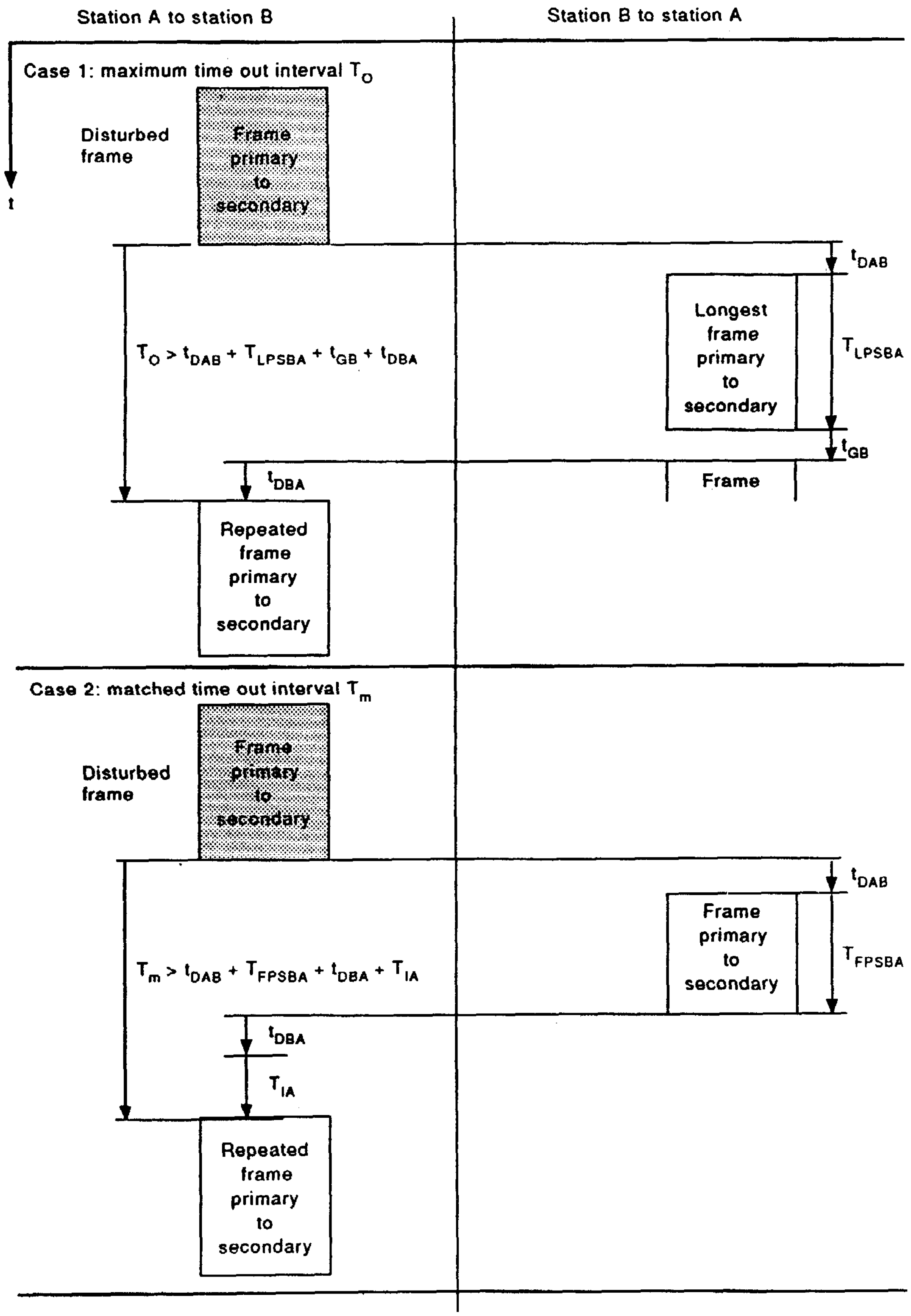

Station A to station B
Station B to station A
Case 1: maximum time out interval T_O
Disturbed frame
Frame primary to secondary
t
t_{DAB}
Longest frame primary to secondary
T_{LPSBA}
$T_O > t_{DAB} + T_{LPSBA} + t_{GB} + t_{DBA}$
t_{GB}
t_{DBA}
Frame
Repeated frame primary to secondary
Case 2: matched time out interval T_m
Disturbed frame
Frame primary to secondary
t_{DAB}
Frame primary to secondary
T_{FPSBA}
$T_m > t_{DAB} + T_{FPSBA} + t_{DBA} + T_{IA}$
t_{DBA}
T_{IA}
Repeated frame primary to secondary

Figure A.3 – Balanced transmission procedures, disturbed primary frame

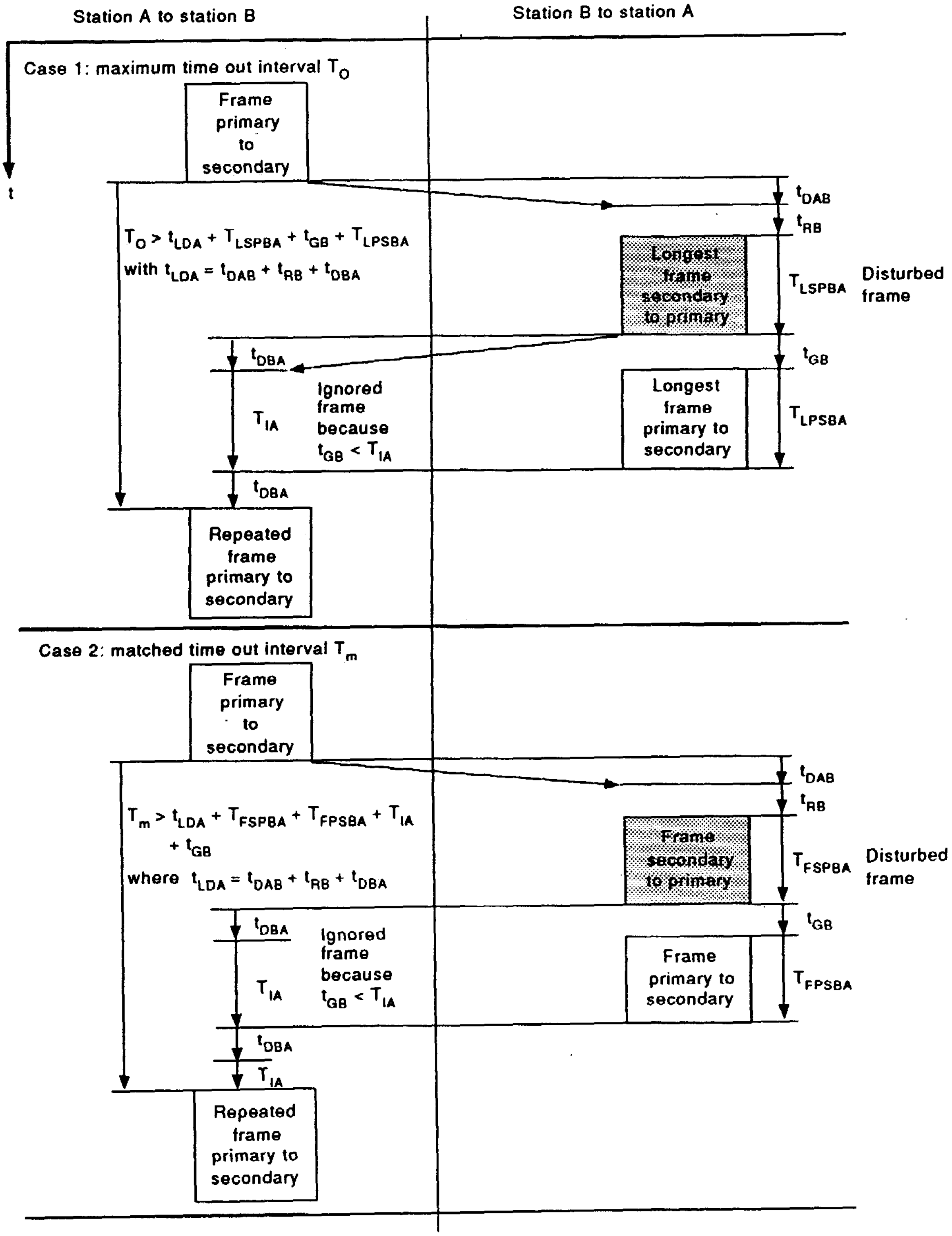

Station A to station B
Station B to station A
t
Case 1: maximum time out interval T_O
Frame primary to secondary
t_{DAB}
t_{RB}
$T_O > t_{LDA} + T_{LSPBA} + t_{GB} + T_{LPSBA}$
with $t_{LDA} = t_{DAB} + t_{RB} + t_{DBA}$
Longest frame secondary to primary
T_{LSPBA}
Disturbed frame
t_{DBA}
t_{GB}
T_{IA}
Ignored frame because $t_{GB} < T_{IA}$
Longest frame primary to secondary
T_{LPSBA}
t_{DBA}
Repeated frame primary to secondary
Case 2: matched time out interval T_m
Frame primary to secondary
t_{DAB}
t_{RB}
$T_m > t_{LDA} + T_{FSPBA} + T_{FPSBA} + T_{IA} + t_{GB}$
where $t_{LDA} = t_{DAB} + t_{RB} + t_{DBA}$
Frame secondary to primary
T_{FSPBA}
Disturbed frame
t_{DBA}
t_{GB}
T_{IA}
Ignored frame because $t_{GB} < T_{IA}$
Frame primary to secondary
T_{FPSBA}
t_{DBA}
T_{IA}
Repeated frame primary to secondary

Figure A.4 – Balanced transmission procedures, disturbed secondary frame

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This Indian Standard has been developed from Doc : No. LTD 25 (1740).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at Printograph, New Delhi, Ph : 5726847